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YILDIZ TECHNICAL UNIVERSITY
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DEPARTMENT OF FOREIGN LANGUAGES EDUCATION
ENGLISH LANGUAGE EDUCATION

MASTER'S THESIS

COMPARATIVE ANALYSIS OF HUMAN AND CHATBOT INTERACTIONS IN ENGLISH AS A FOREIGN LANGUAGE LEARNING: A NEUROSCIENTIFIC PERSPECTIVE

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Gamze TURUN tarafından hazırlanan "Yabancı Dil Olarak İngilizce Öğreniminde İnsan ve Chatbot Etkileşimlerinin Karşılaştırmalı Analizi: Nörobilimsel Bir Perspektif" başlıklı çalışma, **08/05/2025** tarihinde yapılan savunma sınavı sonucunda oy birliği ile başarılı bulunmuş ve jürimiz tarafından Yabancı Diller Eğitimi Bölümü, İngiliz Dili Eğitimi Programında **YÜKSEK LİSANS** tezi olarak kabul edilmiştir.

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ABSTRACT

COMPARATIVE ANALYSIS OF HUMAN AND CHATBOT INTERACTIONS IN ENGLISH AS A FOREIGN LANGUAGE LEARNING: A NEUROSCIENTIFIC PERSPECTIVE

Interaction is considered essential in the context of language acquisition, as it facilitates practice, enables feedback, and fosters meaningful communication. Although language learning has traditionally relied on human-to-human interaction, the integration of artificial intelligence has introduced chatbot-mediated exchanges, offering more personalized and easily accessible language practice. Despite growing interest in these technologies, the cognitive and emotional differences between human-human interaction (HHI) and human-computer interaction (HCI) remain underexplored, particularly at the neural level. The primary aim of this research is to address this gap by examining neural activity, especially alpha and theta oscillations, during real-time English-speaking tasks in Human-Human Interaction (HHI) and Human-Computer Interaction (HCI) by employing an electroencephalography (EEG) technique. Accordingly, the analysis of alpha and theta oscillations sheds light on the underlying cognitive and emotional mechanisms underpinning interaction in each context.

Adopting a quasi-experimental mixed-methods design, the study involved 37 ELT students (20 in HCI, 17 in HHI) and was conducted in a hospital setting under neurologist supervision. EEG data collected during spontaneous English-speaking tasks were analyzed using frequency (power spectral) analysis and independent samples t-tests. Qualitative data from semi-structured interviews were analyzed through thematic analysis. The results indicated significant differences in alpha and theta activities between the two conditions. The HHI group exhibited higher alpha activity in frontal regions, while the HCI group had greater alpha in temporal regions. Additionally, the HCI group exhibited heightened theta activity in both frontal and temporal areas, suggesting distinct cognitive and emotional engagement patterns. Qualitative findings supported these results, highlighting that participants in HHI valued emotional connection and spontaneous interaction, while those in HCI appreciated the reduced pressure of chatbot communication. Participants also noted limitations in chatbot understanding and naturalness. This study contributes to neurocognitive language research and offers insights for designing more effective, learner-centered AI-enhanced language learning environments.

Keywords: Human-Human Interaction, Human-Computer Interaction, Electroencephalography, Alpha activity, Theta Activity, Real-time English Speaking, English Language Teaching

ÖZET

YABANCI DİL OLARAK İNGİLİZCE ÖĞRENİMİNDE İNSAN VE CHATBOT ETKİLEŞİMLERİNİN KARŞILAŞTIRMALI ANALİZİ: NÖROBİLİMSEL BİR PERSPEKTİF

Etkileşim, pratik yapma, geribildirim alma ve anlamlı iletişim kurma fırsatları sunduğu için dil ediniminde temel bir unsur olarak görülmektedir. Dil öğrenimi geleneksel olarak insan-insan etkileşimine dayanırken, yapay zekânın entegrasyonu, daha kişiselleştirilmiş ve kolay erişilebilir dil pratiği sunan sohbet botu aracılı iletişimi beraberinde getirmiştir. Artan ilgiye rağmen, insan-insan etkileşimi (İİE) ile insan-bilgisayar etkileşimi (İBE) arasındaki bilişsel ve duygusal farklılıklara, özellikle nöral düzeyde odaklanan çalışmalar alanyazında oldukça sınırlıdır. Bu araştırmanın temel amacı, elektroensefalografi (EEG) yöntemi kullanarak İİE ve İBE sırasında gerçek zamanlı İngilizce konuşma esnasında beyin aktivitesini, özellikle alfa ve teta dalgalarını, incelemektir. Çalışma, bu iki etkileşim türü arasında alfa ve teta aktivitelerinin farklılık gösterip göstermediğini araştırmakta; bu beyin dalgaları aracılığıyla etkileşimi şekillendiren bilişsel ve duygusal süreçlere dair içgörüler sunmayı amaçlamaktadır.

Yarı deneysel karma yöntem deseninin benimsendiği çalışmada, biri İBE (n=20), diğeri İİE (n=17) olmak üzere toplam 37 İngilizce Öğretmenliği lisans öğrencisi yer almıştır. Çalışma, tam donanımlı bir hastane ortamında, bir nörolog gözetiminde yürütülmüştür. Katılımcılar, spontane konuşma görevlerini tamamlarken EEG verileri Neuron-Spectrum.NET cihazı ile toplanmış, veriler frekans (güç spektral) analizi ile incelenmiş ve bağımsız örneklemler t-testi ile karşılaştırılmıştır. Ayrıca, katılımcılarla yarı yapılandırılmış görüşmeler gerçekleştirilmiş veriler tematik analiz yoluyla değerlendirilmiştir. Sonuçlar, iki grup arasında alfa ve teta aktivitesinde anlamlı farklılıklar olduğunu göstermiştir. İİE grubunda frontal bölgelerde daha yüksek alfa aktivitesi gözlemlenirken, İBE grubunda temporal bölgelerde daha belirgin alfa aktivitesi tespit edilmiştir. Ayrıca, İBE grubunda frontal ve temporal bölgelerde daha yüksek teta aktivitesi kaydedilmiştir. Bu bulgular, iki etkileşim türünde farklı bilişsel ve duygusal katılım desenlerine işaret etmektedir. Nitel veriler de bu sonuçları desteklemektedir. İİE'deki katılımcılar, duygusal ve doğal etkileşimin önemini vurgularken; İBE'deki katılımcılar, chatbot iletişiminin daha az stresli olduğunu vurgulamıştır. Bununla birlikte, bazı katılımcılar chatbotların anlama kapasitesi ve doğallığı konularında sınırlamalar olduğunu ifade etmiştir. Bu çalışma, nörobilişsel dil araştırmalarına katkıda bulunmakta ve öğrenci merkezli, yapay zeka destekli dil öğrenme ortamlarının tasarımı için içgörüler sunmaktadır.

Anahtar Kelimeler: İnsan-İnsan Etkileşimi, İnsan-Bilgisayar Etkileşimi, Elektroensefalografi, Alfa Aktivitesi, Teta Aktivitesi, Gerçek Zamanlı İngilizce Konuşma, İngiliz Dili Eğitimi

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"If the small view seen through the keyhole is enough for you, let it be, but I need to swim in those waters."

Gamze TURUN
May, 2025, İstanbul

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LIST OF ABBREVIATIONS

HHI:	Human-Human Interaction
HCI:	Human-Computer Interaction
HMI:	Human-Machine Interaction
EEG:	Electroencephalography
STM:	Short-Term Memory
LTM:	Long-Term Memory
WM:	Working Memory
AI:	Artificial Intelligence
FLA:	Foreign Language Acquisition
SLA:	Second Language Acquisition
FLSA:	Foreign Language Speaking Anxiety
FLCAS:	Foreign Language Classroom Anxiety Scale
CASA:	Computers are Social Actors
L2:	Second Language
EFL:	English as a Foreign Language
IELTS:	International English Language Testing System
F:	Frontal
C:	Central
T:	Temporal
P:	Parietal
O:	Occipital
DoG:	Declaration of Helsinki
WMA:	World Medical Association
MALL:	Mobile-Assisted Language Learning
VRET:	Virtual Reality Exposure Therapy
IPAs:	Intelligent Personal Assistants
WTC:	Willingness to Communicate
NLP:	Natural Language Processing
ZPD:	Zone of Proximal Development
fMRI:	functional Magnetic Resonance Imaging

1. INTRODUCTION

This chapter consists of 6 sections. The first section, background to the study, introduces an overview of the role of interaction in language acquisition by emphasizing its critical role for language learners to improve their language skills. This section further demonstrates how cognitive factors, especially memory and emotional factors, especially speaking anxiety, influence the efficacy of interaction. This section further introduces two distinct interaction types: human-human interaction (HHI) and human-computer interaction (HCI), highlighting the growing influence of Artificial Intelligence (AI)-mediated tools such as chatbots. Additionally, it outlines the electroencephalography (EEG) as a method for investigating brain activity during interaction, focusing on alpha and theta brainwave oscillations, which are associated with memory and relaxation. The second section, the statement of the problem, totally focuses on the critical gaps in the literature by providing existing research that highlights the limited exploration of neural mechanisms in language interactions. This part aims to provide a clear depiction of the potential impact and the significance of the study and its potential to fill the essential gaps in the field of language acquisition. In the third section, the purpose of the study, the ultimate aims of the study are highlighted explicitly. The fourth section, the significance of the study, offers greater insights into the pivotal role of the study by following the fifth section, research questions of the study. Finally, the last section identifies key terms in the literature.

1.1. Background to Study

Interaction plays a paramount role in language acquisition (Gass et al., 1998) since it serves as a core mechanism providing opportunities for learners to practice, receive feedback (Swain, 1985), and engage in meaningful communication (Pica, 1994; Long, 1996). However, its efficacy is affected by several cognitive and emotional factors. Speaking anxiety and memory mechanisms are two of these factors that profoundly shape the quality and success of language interactions. Horwitz et al. (1986) and Young (1991) assert that speaking anxiety poses greater challenges than other language skills (reading, writing, listening) since it necessitates real-time contact.

Previous research reports fear of making mistakes, fear of being judged (Pertaub et al., 2001), lack of practice (Alnahidh & Altalhab, 2020), teacher misconceptions (Young, 1991), and previous negative experiences (Riasati, 2011) as the main reasons triggering speaking anxiety. Apart from emotional factors, cognitive processes and memory significantly influence the overall outcome of the interaction since human memory and language are closely intertwined concepts (Baddeley, 1992). Memory, in the realm of language acquisition, represents the brain's capacity to encode, retain, and subsequently retrieve knowledge. It is commonly classified into 2 general categories: short-term memory (STM) and long-term memory (LTM). STM refers to a cognitive process that temporarily retains of sensory events, actions, and cognitive information (Kolb & Wishaw, 2009; Neath et al., 2005; Klingberg, 2010) while LTM characterized as the capacity to learn new information, facts, and knowledge, and retrieve this data after a certain duration. Along with STM and LTM mechanisms, working memory (WM) is an essential concept in language processing since it refers to a neural system that enables both temporary retention and mental manipulation, which is vital for complex cognitive tasks, including language comprehension and learning (Baddeley, 1992). Ultimately, both memory and speaking anxiety have major effects on the success and utility of interactions in language acquisition, since they collaboratively influence a learner's capacity to retain knowledge and communicate effectively under pressure.

From the lens of HHI, language acquisition has been traditionally viewed as a bridge between the input and output processes (Long, 1996). However, with the advent of Artificial Intelligence (AI) technology, new forms of interaction, including HCI, especially chatbot-mediated conversations, are introduced. AI is a technology that is claimed to imitate human intellect (Kok, 2009). With the burgeoning adoption of this technology into language teaching and learning processes, a new form of interaction has emerged: human-AI interaction, particularly involving engaging with chatbots. Chatbots are software programs providing opportunities for language learners, such as personalized (Ruan et al., 2019), interactive (Fryer et al., 2019), engaging learning experiences through stimulating human-like conversations. Since they are ubiquitous (Garcia, Fuertes & Molas, 2018) and give immediate responses and feedback (Chen et al., 2023), they have been widely utilized in language education. Despite the increasing usage of chatbots in language education, concerns persist regarding their limitations, such as inaccurate information (Bowman, 2022), inability to fully simulate human

emotions (Chen et al., 2023), and declining engagement over time due to the fading novelty effect (Fryer et al., 2019). These concerns have led to an expanding corpus of research that contrasts the efficacy of HCI with conventional HHI in language acquisition. While some scholars suggest that individuals adopt an intentional attitude when interacting with other humans, they do not exhibit the same behavior toward chatbots (Rauchbauer et al., 2020), The Computers Are Social Actors (CASA) theory assert that individuals engage with computers similarly to their interactions with human individuals (Nass, Steuer, & Tauber, 1994). Despite the perspectives towards the two types of interactions differ, the nature of engagement is multifaceted, encompassing not only social interaction but also cognitive and emotional processes. In HHI, the learners receive simultaneous response, authentic language use, and emotional feedback, and generally more immersive experiences (Tai, 2024). This nature of HHI can trigger deeper cognitive involvement. On the other hand, in human-AI interaction, particularly with chatbots, they experience a less natural environment compared to HHI since chatbots do not fully imitate human emotions (Chen et al., 2023), resulting in a weaker emotional connection (Annamalai et al., 2023). Therefore, questions about the cognitive processes involved in HHI compared to HCI have arisen with the differentiations in interaction. To investigate these cognitive differences, researchers have increasingly employed neurophysiological recording techniques, such as EEG, a unique technique to record electrical brain activity from the human scalp (Harmon-Jones and Amodio, 2012, p. 503). EEG devices can provide real-time information about the connections between mental and physical processes (Nacke, Stellmach, & Lindley, 2010) during language tasks to enrich the knowledge on the brain's responses to different interaction types. Specific brain oscillations, particularly alpha and theta rhythms, are crucial for analyzing cognitive and attentional processes. Alpha activity is not only associated with relaxation but also linked to the memory mechanisms (Sauseng et al., 2002). After researching the alpha brainwaves, Klimesch (1997) concluded that it is closely related to memory performance, an important factor influencing interaction. Meanwhile, theta activity is also tied to memory (Jensen et al., 2002) and additionally reflects mental calmness and meditative states (Banquet, 1972, 1973), the polar opposite of anxiety. Measuring the differences between alpha and theta power during HHI and HCI will enhance our understanding of how these interaction types engage in cognitive and emotional sources, especially memory and emotional regulation, during a real-time English-speaking task.

1.2. The Statement of the Problem

Interaction has long been regarded as an essential aspect of language learning, particularly in foreign language acquisition (FLA), attracting substantial research interest in the field. Interaction has been traditionally addressed to HHI (Krashen, 1985; Long, 1996; Muho & Kurani, 2014; Sato, 1986; Swain, 1985; Vygotsky, 1978), a cornerstone of language acquisition in the literature. With the rise of HCI, especially AI-driven tools such as chatbots, a new dynamic emerged in the literature in the realm of language acquisition (Hill et al., 2015; Mou & Xu, 2017; Reeves & Nas, 1996; Shen & Wang, 2023; Tai, 2024). The rapid development of AI has accelerated HCI, adding a new dimension to the literature by enabling comparisons between HHI and HCI (Bowman, 2022; Rahman & Tomy, 2023). However, the interactional differences between HHI and HCI in language learning remain inconclusive and underexplored from a cognitive and emotional processing perspective.

The extensive body of research has predominantly focused on behavioral outcomes and learner attitudes, with insufficient investigation into the neural mechanisms underlying these interactions. Memory and speaking anxiety, main factors influencing the efficacy of interactions in the realm of FLA, have been also pervasively investigated in the literature, yet much of the existing research on anxiety and memory in language learning has relied on self-reported data or behavioral assessments (Aida, 1994; Horwitz et al., 1986; MacIntyre, 1991). However, the investigation of how learners process information and regulate emotions in real-time during interactions (both HHI and HCI), especially within the pressure of anxiety and memory mechanisms, remains rather opaque from a neurocognitive perspective.

EEG presents a promising method for addressing this gap by delivering real-time insights into brain activity associated with memory retention, attention, and emotional regulation during language tasks. EEG is a non-invasive measurement technique that opens a “window on the mind” (Nunez & Srinivasan, 2006, p.2424), and it is widely employed in cognitive and clinical research (Smith, 2005; Beebe et al., 2010; Zhang et al., 2011; Gola et al., 2013). However, in the field of language acquisition, the usage of that unique device is rather infrequent. The existing literature examined mostly bilingualism by employing it (Momenian et al., 2024; Soman et al., 2019), yet its application in dynamic, real-time second language speaking tasks remains limited. Existing studies utilized an EEG device pervasively focused on tasks like vocabulary

retention (Jensen et al., 2002; Klimesch, 1999) and attention (Gerlic & Jausovec, 2001). More dynamic processes of real-time communication, including speaking and listening, were overlooked, even though EEG has shown promise as a reliable tool for examining speech production processes (Hagoort & Van Turennout, 1997). Moreover, previous research highlighted the need for further studies utilizing EEG in speech assessment (Adjouadi et al., 2004; Calliess & Schultz, 2006).

Furthermore, alpha and theta oscillations, two EEG frequency bands, are especially relevant for this purpose. Alpha activity has been linked to both memory performance and states of relaxation, while theta activity is associated with memory encoding and emotional regulation, including meditative and low-anxiety states (Sauseng et al., 2002; Banquet, 1972, 1973; Jensen et al., 2002). Yet, research comparing alpha and theta activity during HHI and HCI remains scarce. Hsu (2022) took an initial step by using a portable EEG device to compare attention and relaxation in HHI vs. HCI, but the use of advanced EEG systems in such comparisons, especially in speaking tasks, is still rare.

1.3. The Purpose of the Study

The primary purpose of this study is to investigate cognitive and emotional processes underlying HHI and HCI during real-time English speaking tasks in the context of FLA. Specifically, the study focuses on examining EEG-based neural activity, particularly alpha and theta oscillations that are commonly associated with cognitive states such as memory performance and emotional regulation, including relaxation, which contrasts with speaking anxiety (Klimesch, 1997).

Given the growing integration of AI-driven tools such as chatbots into language learning and the lack of consensus on their comparative efficacy with traditional HHI, this study seeks to contribute to the field by providing neurophysiological evidence using EEG. By measuring alpha and theta brainwave activity, the study aims to investigate whether and how neural responses differ between HHI and HCI during spontaneous speaking tasks. In addition to EEG data, the study incorporates learners' perceptions of both interaction types to offer a more comprehensive understanding of their experiences. This qualitative data serves to triangulate and contextualize the neural findings, enhancing the interpretation of brain-based indicators of cognitive and emotional engagement.

Ultimately, this study aims to advance understanding of how different forms of interaction impact the neurocognitive processes involved in second language use. The findings are expected to provide insights that can inform more effective, brain-aware strategies in language teaching and learning, while also contributing to the growing field of neurocognitive research in language studies.

1.4. The Significance of the Study

This research is significant for several reasons. Since there is currently no consensus in the literature regarding the differences between HHI and HCI in FLA, particularly in speaking. Although prior research has thoroughly examined these interaction types concerning behavioral and psychological impacts, there is limited understanding of the real-time brain mechanisms that facilitate these interactions (Müller et al., 2021). By employing an EEG device to measure alpha and theta oscillations that are commonly linked to emotional regulation and cognitive processing, this study aims to offer new insights into how learners experience HHI and HCI during spontaneous English-speaking tasks.

Second, this study might contribute to the optimization of foreign language learning processes. AI-driven tools, especially chatbots, have raised extensive questions in terms of the efficacy of language teaching and learning strategies (Bowman, 2022). The results of this study could play a role in eliminating uncertainty in its potential to replace human interlocutors by providing neural data. Understanding the cognitive and emotional responses triggered by human and AI-mediated interactions in English-speaking as a foreign language may facilitate the development of personalized learning environments that better support individual learners.

Finally, given the lack of neurocognitive language research, this research can contribute to the emerging field of neurocognitive language research. It offers a novel method to examine the effects of interaction type on brain activity during dynamic language use. Therefore, it aims to expand our empirical understanding of how technology, especially AI-mediated chatbots, interface with cognitive and emotional processes in language learning.

1.5. Research Questions

This research aims to answer the following research questions:

1. Does alpha activity, as measured by an EEG device, differ between human-human interaction (HHI) and human-chatbot interaction during real-time English-speaking tasks among English language learners?
2. Does theta activity, as measured by an EEG device, differ between human-human interaction (HHI) and human-chatbot interaction during real-time English-speaking tasks among English language learners?
3. What are English language learners' perceptions of human-human (HHI) and human-computer interaction (HCI) using AI-mediated tools, like chatbots, in English-speaking tasks?

1.6. Definition of Key Terms

Interaction: Interaction refers to the process of communication where individuals work together to achieve mutual understanding, especially by clarifying and adjusting their language when confusion arises (Ellis, 1999).

Human-human Interaction (HHI): Human-human interaction refers to the process by which individuals communicate or engage with each other, utilizing verbal and non-verbal methods to exchange information, express emotions, and construct meaning (Aleixo et al., 2024).

Human-computer Interaction (HCI): Human-Computer Interaction (HCI) is a field focused on creating, assessing, and applying interactive computer systems intended for human users, as well as investigating significant phenomena associated with these systems (Hewett et al., 1992).

Electroencephalography (EEG): EEG is a pervasive and non-invasive technique used to record electrical brain activity, helping researchers gain better insight into brain functions (Teplan, 2002).

Artificial intelligence (AI): Artificial intelligence (AI) is a field of computer science focused on emulating human intelligence within computer systems. It enables computers to perform human tasks, participate in logical thought processes, and make decisions by developing programs that replicate human behavior (Kok, 2009).

Chatbots: Chatbots, also known as chatterbots, are software programs that simulate human-like conversations through text or text-to-speech functions (Caldarini, Jaf, & McGarry, 2022).

Foreign Language Acquisition (FLA): Foreign language learning occurs in settings where the target language is not commonly spoken in daily life. In such environments, learners typically rely on structured, formal instruction rather than natural communication for developing language skills (Oxford, 1990).

Alpha Oscillation: Alpha is the predominant brain wave pattern in the typical human EEG, characterized by oscillations in the frequency range of 8 to 13 Hz (Andreassi, 2007)

Theta Oscillation: Theta activity refers to a type of brain wave pattern characterized by oscillations within the frequency range of approximately 4 to 8 Hz (Başar, 1999).

Prefrontal Cortex (FP1 and FP2): The FP1 electrode site is positioned on the far-left side of the brain's frontal lobe. This area is primarily associated with key cognitive functions, including attention, concentration, decision-making, planning, task execution, retrieval of verbal episodic memories, and visual working memory (Chapin & Chapin-Russell, 2014).

The FP2 site is located in the right frontal lobe of the brain, specifically within the prefrontal cortex. It is involved in emotional attention, judgment, self-awareness, impulse control, face and object recognition, emotional regulation, and verbal episodic memory (Russell-Chapin et al., 2020)

Frontal Lobes (F3, FZ, F4, F7 and F8):

The F3 region, situated in the left frontal lobe of the brain, plays a crucial role in various cognitive and motor functions. Specifically, it supports motor planning, fine motor coordination of the right upper extremities, retrieval of visual episodic memories, object processing, emotional interpretation, and contributes to positive mood regulation (Chapin & Russell-Chapin, 2014).

The F4 site, located in the right frontal lobe of the brain, is primarily responsible for motor planning, fine motor coordination of the left upper limbs, verbal episodic and semantic memory retrieval, as well as the regulation of attention and impulse control (Chapin & Russell-Chapin, 2014).

The FZ site, located at the midline of the frontal cortex, is associated with abstract reasoning, conscious thought, planning, and emotional regulation (Chapin & Russell-Chapin, 2014).

The F7 site, located in the left frontal lobe, is involved in verbal expression, speech fluency, cognitive mood regulation, working memory (both visual and auditory), and attentional control, particularly associated with Broca’s area, a region critical for

speech planning and production. It also engages with the amygdala as part of the social brain, and contributes to executive functioning (Carter, 2014)

The F8 site, located in the right frontal lobe, is part of the prefrontal cortex involved in emotional expression, face recognition, drawing, visual-spatial working memory, sustained attention, and mood regulation. This area plays a role in integrating emotional processing and guiding movements through internal and external cues, supporting both cognitive and behavioral control (Chapin & Russell-Chapin, 2014).

Central Region (C3, CZ and C4):

The C3 site, located in the frontal lobe between CZ and T3. It facilitates communication between sensory and motor systems, enabling coordinated physical actions. In addition, C3 is associated with short-term memory, handwriting, and alerting responses (Stuss, 2011).

The CZ site, located at the midline of the scalp, lies within both the sensory and motor cortices, directly above the basal ganglia. CZ is especially important for sensorimotor rhythm and overall motor control, supporting the integration of sensory experiences into coordinated physical actions (Chapin & Russell-Chapin, 2014).

The C4 site is positioned in the right hemisphere of the central brain. It plays a key role in sensorimotor integration, short-term memory, calming responses, and is also associated with left-handed motor control. (Chapin & Russell-Chapin, 2014).

Temporal Lobes (T3, T4, T5 and T6):

The T3 site is situated in the left anterior temporal lobe, just behind the mastoid bone located behind the ear. This brain region is closely linked to functions such as language comprehension, processing of sensory input, and memory retention (Russell-Chapin et al., 2020).

The T4 site is positioned near the right ear, specifically in the frontal region of the right temporal lobe within the right cerebral cortex. This site is a component of the primary auditory cortex and maintains neural connections with the limbic system (Russell-Chapin et al., 2020).

The T5 site is situated in the left temporal lobe of the brain. It is primarily involved in supporting logical reasoning and verbal comprehension, making it an important region for language processing and analytical thinking (Russell-Chapin et al., 2020).

The T6 region is located in the right temporal lobe. This area is associated with processing emotional understanding, as well as recognizing faces and symbols,

playing a key role in nonverbal communication and visual processing (Chapin & Russell-Chapin, 2014).

Parietal Lobes (P3, PZ and P4):

The P3 site, located in the left hemisphere of the parietal lobe. It is important in interpreting spatial and relational concepts, integrating multimodal sensory input, performing calculations, coordinating voluntary movement (praxis), and supporting verbal reasoning abilities (Russell-Chapin et al., 2020).

The PZ site, located at the midline of the parietal lobe, is particularly associated with self-representation, self-monitoring, and the resting state of consciousness (Chapin & Russell-Chapin, 2014).

The P4 region, situated in the right parietal lobe, is involved in integrating sensory input and supporting spatial awareness (Russell-Chapin et al., 2020).

Occipital Lobes (O1 and O2): The O1 and O2 sites, located in the left and right occipital lobes, are primarily responsible for visual processing (Russell-Chapin et al., 2020).

2. LITERATURE REVIEW

In this literature review, the definition of interaction, key elements influencing interaction in language acquisition contexts (e.g., speaking anxiety and memory), its types (e.g., human-human and human-AI), and the role of interaction in language acquisition are emphasized due to the critical role of interaction in the current study. By comparing HHI and HCI, this review aims to highlight the lack of consensus in the existing literature regarding the effectiveness of these forms in FLA. This comparison will be supplemented with a discussion of AI tools, particularly chatbots, and their integration into FLA based on pertinent studies. Additionally, this review introduces the EEG and explores brain oscillations, specifically alpha and theta power, as a methodological approach to understanding cognitive and emotional processes in language learning. The goal is to establish a framework for the current research by providing empirical evidence and identifying gaps in the literature, particularly utilizing EEG to assess language acquisition dynamics during both human and AI-mediated interactions.

2.1. Interaction in Foreign Language Acquisition

Saffer (2009) defines "interaction" as a broad transaction involving the exchange of information between two entities, which can include people, machines, and systems in various combinations. Wagner (1994) expands on this by describing interaction as "reciprocal events requiring at least two objects and two actions, where these elements mutually influence one another" (p. 8). In contrast, Daniel and Marquis (1988) take a more restrictive approach, limiting interaction to instances where a student is in two-way contact specifically with another person or group (p. 339). Through these definitions, it is evident that interaction is vital for facilitating communication. In the context of language acquisition, interaction becomes inherently intertwined with language itself, supporting effective communication and learning (Loewen & Sato, 2018). This dynamic is not only indispensable for the acquisition of a second language but also underpins everyday language use. As such, the role of interaction has long

been fundamental to the study of language acquisition, and it significantly influences the process of FLA (Gass et al., 1998). Interaction offers learners an opportunity to modify their linguistic output (Swain, 1985) and receive comprehensible input and feedback (Long, 1996; Pica, 1994). In line with this, Long (1996) argues in his Interactive Hypothesis that conversational interaction helps learners acquire language by linking the input they receive (what they hear and read), their internal cognitive processes, and their output (what they produce), particularly by focusing their attention on productive ways. In addition, according to Swain's Output Hypothesis (1985), which highlights the significance of actively using language (speaking, writing) in the process of learning, interaction offers chances for generating language, which in turn contributes to the development of language skills. While Long's hypothesis emphasizes the role of input, Swain focuses on the productive use of language in interaction as a key driver of acquisition. In the same vein, Gass and Varonis (1994) argue that interaction forms the basis for the development of syntax in a second language. Rather than simply providing practice for grammatical structures, interaction shapes language production through both immediate and subsequent exchanges. Additionally, through interaction, learners can identify differences between their interlanguage and the target language. This awareness is essential for restructuring their linguistic knowledge, ultimately leading to improved language production. Therefore, the role of interaction in second language acquisition holds merit by providing opportunities for input, output, feedback, and the restructuring of linguistic knowledge (Ellis, Basturkmen & Loewen, 2001; Gass & Mackey, 2014). Expanding on these perspectives, Walsh (2006, 2011) introduces the concept of Classroom Interactional Competence, emphasizing that effective language learning is co-constructed through meaningful and context-sensitive classroom interactions.

Grounded in these theoretical foundations, interaction plays a paramount role in language acquisition by facilitating the exchange of input, output, feedback, and co-construction of meaning. However, its effectiveness is influenced by several cognitive and emotional factors. Among these, speaking anxiety and memory mechanisms are two central factors that significantly impact the quality and success of language interactions (Mora et al., 2023; Schwieter & Wen, 2022).

2.1.1. Speaking Anxiety

Throughout millennia, many researchers and psychologists have defined anxiety in various terms. For instance, Hilgrad et al. (As cited in Scovel, 1978) depicted anxiety as a psychological condition encompassing a sense of fear, tension, nervousness, apprehension, and worry. In psychology, anxiety has been categorized into three aspects, and these are trait anxiety, state anxiety, and situation-specific anxiety. The trait perspective refers to the state when an individual consistently exhibits a tendency towards experiencing anxiety (Scovel, 1978), while state anxiety is defined as an emotional state that is mostly triggered by a temporary stimulus, such as delivering a speech or taking an exam (Spielberger, 1972). Situation-specific anxiety associated with foreign language acquisition is viewed as a distinct form of anxiety that consistently emerges within particular contexts over time (MacIntyre, 1991).

Within the realm of foreign language acquisition, anxiety is a critical factor that can significantly hinder the effectiveness of language interactions. Canadian social psychologists R. C. Gardner and Wallace Lambert, in their groundbreaking research on FLA, particularly in their 1972 work, were among the first to highlight the role of anxiety in foreign language acquisition, and they coined the term ‘’foreign language anxiety’’ (Gardner & Lambert, 1972). Horwitz et al. (1986) defined this form of anxiety as “a distinct complex of self-perceptions, beliefs, feelings, and behaviors related to classroom language learning arising from the uniqueness of the language learning processes” (p.31). Further research, including the development of the Foreign Language Classroom Anxiety Scale (FLCAS) by Horwitz (Aida, 1994), has explored the multilayered nature of foreign language anxiety. The prominent scholars of the field have shown that the emotional reactions of the learners to the language learning and language learning process are inseparable from each other (Horwitz, 1995). For example, MacIntyre and Gardner (1994) conducted a study to investigate the impact of anxiety on second language acquisition at the input, processing, and output phases, to comprehend how anxiety hinders language learning. This study aligns with Krashen’s affective filter hypothesis, depicting anxiety as a barrier to prevent information from reaching the language acquisition area in a learner’s brain (Krashen, 1985). The growing concern about anxiety among foreign language learners has prompted increased research on this issue. This heightened interest is due to anxiety's negative impact on learners’ performance (MacIntyre, 1999; Riasati, 2011) as well as

their motivation and attitudes toward language learning (Phillips, 1990). Furthermore, consistent negative correlations have been reported between foreign language anxiety and a variety of foreign language achievement metrics (Aida, 1994; Clément, 1986; Sanchez-Herrero & Sanchez,1992).

Foreign language anxiety is prevalent in reading (Saito et al., 1999), writing (Li, 2022), listening (Chang, 2008), and speaking (Karataş et al., 2016). However, as interaction is central to language acquisition, foreign language anxiety, especially in speaking, poses a significant challenge (Horwitz et al.,1986; Young, 1991). This heightened anxiety arises since learning a language does not merely rely on memorizing vocabulary and applying grammatical rules, but the essence of it lies in the communication itself. Therefore, foreign language speaking anxiety is a well-recognized hindrance that is pervasive in language classes (Gardner &MacIntyre, 1994). Research has been extensively investigating the causes of Foreign Language Speaking Anxiety (FLSA); fear of making mistakes, fear of being judged (Pertaub et al., 2001), lack of practice (Alnahidh & Altalhab, 2020), teacher misconceptions (Young, 1991), and previous negative experiences (Riasati, 2011) have come to the fore when describing the reasons for the arousal of FLSA. For example, Öztürk (2012) investigated the factors of FLSA in the Turkish context and while gender also played a role, pronunciation and immediate questions were underscored in the study. Besides, notably, a recent study also found that when the learners progress through grades, their anxiety levels tend to increase rather than decrease (Fındıklı &Büyükkarcı, 2023). This suggests that FLSA is influenced by multiple factors, and no single factor is solely responsible for triggering speaking anxiety during interactions.

Speaking anxiety significantly impedes a learner's capacity for meaningful contact, although cognitive factors, particularly memory, are also crucial. Successful engagement in language acquisition depends not just on overcoming emotional obstacles but also on the capacity to access and utilize linguistic knowledge instantaneously. Therefore, understanding the role of memory mechanisms in interaction is essential for exploring how learners process and produce language during communication (Schwieter & Wen, 2022).

2.1.2. Memory in Language Acquisition

Human memory is an essential concept in cognitive psychology and language acquisition since learning and memory are closely related concepts (Baddeley, 1992).

In the context of language acquisition, memory refers to the ability of the brain to encode, store, and later recall information. In the literature, memory is typically classified into 2 general categories: short-term (STM) and long-term memory (LTM). Previous studies define short-term memory as a cognitive system responsible for temporarily holding sensory input, motor information, and cognitive content such as digits, names, words, or similar items (Klingberg, 2010; Kolb & Wishaw, 2009; Neath et al., 2005). On the other hand, long-term memory is defined as the ability to acquire new evidence, facts, and knowledge, and subsequently retrieve this material after a period has elapsed (Izquierdo et al., 1999). However, an essential concept in understanding memory in language learning is working memory (WM). WM was referred to as a brain system that promotes temporary retention and processing of information, and these are essential for cognitive functions such as comprehension, learning, and reasoning (Baddeley, 1992). Additionally, Cowan (2008) regarded WM as encompassing a storage component similar to STM, along with processing mechanisms that facilitate the utilization of STM. In the context of language interaction, these memory systems, particularly working memory and long-term memory, play a pivotal role in memory retention, which is the capability to hold information, and real-time communication. As Ellis (2001, p. 33) suggests, interaction involves simultaneous attention to various elements: the speech of one's conversation partner, sections of the conversation recreated from information stored in LTM, parts of the current visual scene, and scenes recalled from memory. It emphasizes that during interaction, learners must retain and comprehend immediate input from their conversational partner in working memory, while simultaneously retrieving relevant language structures, vocabulary, and prior experiences from LTM to come up with meaningful responses. Therefore, it is essential for maintaining the flow of interaction (Schwieter & Wen, 2022). In similar vein, Klimesch (1994) states that complex cognitive systems such as speaking and thinking, the components of interaction are highly influenced by memory mechanisms. Therefore, understanding how memory mechanisms influence communication is crucial as interaction is fundamental to language development.

As both speaking anxiety and the role of memory highly influence the interaction, they have been the focus of extensive research. However, most studies investigated foreign language speaking anxiety based on behavioural data (Bashori et al., 2022; Botes et al., 2020; Karataş et al., 2016), often collected using the Foreign Language Classroom

Anxiety Scale (FLCAS) by Horwitz (1986) and self-reported data gathered from the surveys, questionnaires, etc. (Hali & Yuningsih, 2024; Khusnia, 2017; Sari, 2017). However, how the learners experience speaking anxiety from a cognitive perspective during real-time interactions remains a gap in the literature.

Besides, a considerable body of research has focused on investigating memory mechanisms through the implementation of memory strategies (Rahayu & Sholikhah, 2024), particularly concerning language learning and retention. However, much of this research has tended to focus on the individual learner's cognitive strategies rather than exploring how memory functions in the context of language interaction synchronously. Therefore, investigating the functions of memory in the context of real-time language interaction through a neuropsychological view remains rather obscure with many of the intricate mechanisms left unexplored.

Understanding the dynamic of interactions, this section will be centered on two prominent forms of interaction: HHI and HCI.

2.2. Human-Human Interaction (HHI) in Foreign Language Acquisition

In this section, among the various forms of interaction, the role of HHI in FLA will be explored, highlighting key theories and related empirical studies. HHI stands for the direct communication between learners and other individuals, including teachers, colleagues, or native speakers, all of whom contribute to the language learning process (Vygotsky, 1978). Lev Vygotsky (1978) highlighted the importance of interaction in language development. In social interaction theory, Vygotsky argues that cognitive development is intricately connected to social interactions. He holds the belief that during social interactions, especially with individuals who possess more knowledge and expertise, such as parents, instructors, or peers, learning takes place. This idea is called the Zone of Proximal Development (ZPD). According to Vygotsky (1978), children first learn through interactions with others (social level) and then internalize this knowledge individually (personal level). This statement highlights that these social interactions between individuals enhance the learners' cognitive abilities. Besides, Krashen (1985) suggests that language acquisition is most effective when learners are exposed to comprehensible input, which is language input that is slightly above their current proficiency level (i+1). HHI naturally generates comprehensible input, as conversational partners adjust their language to ensure comprehension,

thereby promoting the acquisition of new linguistic forms and structures. The significance of HHI in language acquisition has been extensively investigated in the literature. For example, Sato (1986) conducted a longitudinal study on investigating the role of interaction in conversation and revealed that interaction is important for second language (L2) development. This study aligns with the findings of the study conducted by Muho and Kurani (2014), who collected data through a survey that investigated the students' beliefs and opinions on the HHI in second language acquisition.

One form of HHI is peer interaction (also known as student-student interaction). It is defined as "any communicative activity carried out between learners, where there is minimal or no participation from the teacher" (Philp, Adams, & Iwashita, 2014, p. 3). Furthermore, Moore (1989) refers to student-student interaction as the communication between individual students as well as between students in small groups. The advantages of peer interaction in language acquisition have been demonstrated in the literature. For instance, Allwright (1984) argues that learning occurs through peer interactions that involve the presentation of personal value systems in the classroom. Learning is more plausible when learners participate in conversational interactions. During these interactions, they share ideas that hold personal significance, as this type of interaction engages learners in a more meaningful manner. The learners' understanding of language is enhanced by the necessity to modify and employ the language itself, which is a result of the nature of the interaction between the individuals. To support this, Wang and Castro (2010) discovered that learners were more likely to identify the target form in English when they engaged in classroom interaction, particularly through group work. Consequently, language learners experience advantageous outcomes as a consequence of peer interaction (Loewen & Basturkmen, 2005).

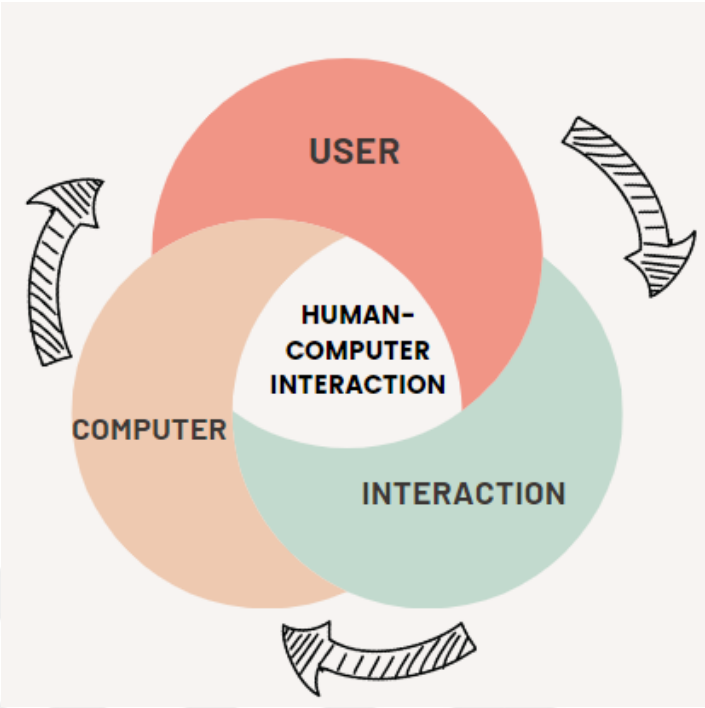
While peer interaction offers unique benefits, the most common form of interaction in language classrooms is teacher-student interaction (Moore, 1989). This interaction is fundamental to guiding and structuring the learning experience, providing learners with the necessary support and feedback to advance their language skills. According to Moore (1989), during ST interaction, the instructor seeks "to stimulate or at least maintain the student's interest in what is to be taught, to motivate the student to learn, to enhance and maintain the learner's interest, including self-direction and self-motivation" (p. 2).

While these foundational studies have offered valuable insights into HHI, recent scholarship has reconceptualized interaction through more dynamic and pedagogically grounded lenses. For instance, Walsh (2006, 2011) introduces the notion of Classroom Interactional Competence (CIC), which emphasizes the ability of teachers and learners to use interaction effectively to create learning opportunities in real-time. Similarly, Markee (2008) highlights how interaction can be examined through Learning Talk Analysis. It focuses on how learning is accomplished moment-by-moment in conversation. These contemporary views position interaction not only as a mechanism for exposure and practice but also as a co-constructed and context-sensitive pedagogic tool.

2.3. Human-Computer Interaction (HCI) in Foreign Language Acquisition

HCI refers to "a discipline concerned with the design, evaluation and implementation of interactive computing systems for human use and with the study of major phenomena surrounding them" (Hewett et al., 1992, p. 5). HCI attempts to comprehend and facilitate the interaction of humans with and through technology (Carroll, 1997). As Figure 1 illustrates, HCI consists of three interconnected elements: the user, the computer, and their interaction. While the user represents the human element, the computer embodies the technology itself. The interaction component, lying at the heart of HCI, emphasizes the dynamic exchanges of information and commands between the user and the system. Moreover, the curricular arrows around the diagram indicate a continuous process of feedback and adaptation, essential for enhancing HCI to meet changing user needs and technical progress.

Figure 1. Human-Computer Interaction



Recently, HCI has gained more attention in language studies with the advent of AI technology (Pikhart, 2020). AI has significantly eased the interaction process by enabling foreign language learners to interact with AI-mediated tools such as chatbots. The term "artificial intelligence" was first coined in 1956 by John McCarthy, Marvin Minsky, Nat Rochester, and Claude Shannon as part of the Dartmouth Summer Research Project (McCarthy, Rochester, & Shannon, 1956). Grounded on computer science technology, AI aims to replicate human intellect in computer systems. It enables computers to fulfill human jobs, make judgments, and engage in logical reasoning by creating computer programs that can imitate human behavior (Kok, 2009). AI technology has been pervasively integrated in English language education, therefore, human-AI interactions have emerged as a significant component of second language acquisition. These interactions involve learners interacting with AI systems, including language learning applications, chatbots, and virtual tutors. Modern intelligent robots not only function as a means of communication but also actively participate in communicative interactions, in contrast to earlier generations of machines that lacked evidence of intelligence (Mou & Xu, 2017). These technologies, including machine learning algorithms and Natural Language Processing (NLP),

provide personalized and adaptive learning experiences, thereby improving educational outcomes (Heift & Chapelle, 2013).

2.4. Human-Human Interaction (HHI) vs. Human-Computer Interaction (HCI)

The comparison between HHI and HCI has caught the attention of prior studies in the field. Dennett (1989) asserted that when interacting with others, individuals take an intentional attitude depending on mental states, intentions, and emotions toward their partners, and this may have an influence on their level of involvement and the results of their learning. This highlights the unique dynamics present in HHI compared to human-computer interactions. Unlike HHI, individuals may not hold negative or positive attitudes towards artificial agents like conversational robots during interaction (Rauchbauer et al., 2020). However, the Computers Are Social Actors (CASA) theory asserts that individuals perceive and engage with computers like their interactions with human individuals (Nass, Steuer, & Tauber, 1994; Nass & Moon, 2000). The CASA paradigm was developed by an accumulation of empirical data obtained from human-computer interaction trials. Reeves and Nass (1996) explicitly selected certain discoveries from social science research and replicated the functionality of individuals who were using computers or televisions. At the end of these investigations, Reeves and Nass (1996) introduced the media equation hypothesis, which claims that individuals consider computers as if they were actual human beings and tend to apply the same social norms, expectations, and assumptions.

Since there is uncertainty in this context, this section intends to provide insights into the diverse impact of intentional attitudes in human-human versus human-computer interactions by integrating empirical studies.

Tai (2024) conducted a recent study that compared the impact of out-of-class interactions with intelligent personal assistants (IPAs) and human interlocutors on English as a Foreign Language (EFL) learners' willingness to communicate (WTC) beyond the classroom. The participants were divided into two groups: the HCI group (they interacted with IPAs such as Siri, Alexa) and the HHI group (they interacted with human interlocutors). Data were collected through surveys and interviews before and after the intervention to measure changes in WTC. The results showed that the HHI group reported higher satisfaction and found the interactions to be more engaging than the HCI group. Besides, both groups showed an increase in WTC, but the group that

interacted with human interlocutors exhibited a more significant increase compared to the IPA group. Another study by Shen and Wang (2023) explored whether speakers align their lexical choices differently when interacting with a human or a computer, as well as the impact of individuals' social skills on the strength of lexical alignment in these contexts. The study refers to alignment in the context of linguistics and conversation as the phenomenon where people tend to adopt and mimic each other's linguistic expressions, behaviors, or styles during communication. The results showed that lexical alignment was stronger in HCI (79.5%) compared to HHI (58.6%). The study suggests a potential boundary in how speakers perceive and respond to human versus computer interlocutors. The stronger lexical alignment in HCI indicates that people might adapt their language more when they believe they are interacting with a computer, possibly due to the absence of social pressures that exist in human interactions. Likewise, Mou and Xu (2017) investigated the differences in human personality traits and communication attributes when interacting with AI in comparison to other humans. The participants were divided into two groups. One group viewed transcripts of interactions between a human and the chatbot Little Ice, while the other group viewed transcripts of interactions between two humans. The findings showed that participants exhibited different personality traits when interacting with AI compared to human interactions. Accordingly, participants were more open in HHI than in human-AI interactions.

However, Hill et al. (2015) investigated the differences in communication behaviours when people interact with other humans versus when they interact with a chatbot, revealing that participants feel less restrained or judged when communicating with an AI. In terms of second language production, Haristiani's (2019) findings offer a deep understanding of the comfort provided by the chatbots to the learners. The study lays bare the sense of ease and relaxation experienced during interactions with chatbots contrast to the potential anxiety often associated with peer or teacher interactions.

While HHI is essential for language acquisition, it can also trigger anxiety, particularly in face-to-face speaking situations. Rahman and Tomy (2023) aimed to compare HHI and HCI to examine the influence of Intelligent Personal Assistants (IPAs) on alleviating FLSA. It was conducted over 16 weeks when the learners engaged in IPA-assisted language learning activities and sought to show both quantitative and qualitative results of the study. It was revealed that there was a significant reduction in anxiety levels (from a mean score of 3.99 to a mean score of 3.17), and the students

expressed their conformity and the feeling of being less judged compared to speaking with peers or teachers. Furthermore, Chen et al. (2024) also explored methods of integrating technology into language learning to mitigate speaking anxiety and compared the effectiveness of traditional lecture-based instruction, mobile-assisted language learning (MALL), and virtual reality exposure therapy (VRET) in this case. The study found that all three groups exhibited a reduction in anxiety level, whereas the VRET group showed a statistically significant decrease.

In addition, the literature highlights the importance of the approach taken by the learners in interaction with AI, showing how these factors are interdependent. For example, in their recent study Wang et al. (2023) provided further insights into the nature of human-computer interactions in the context of language acquisition. The study investigated how the students interact with AI in an EFL environment by considering the factors affecting AI-supported EFL learning. The research was carried out in real-life learning environments and included sixteen elementary school children for around three months. The findings underscored that AI's potential was not accessible to all students. The results demonstrated that a comprehensive approach to AI-supported learning could significantly improve the advantages of AI's personalized guidance and reinforce the human-AI learning community. In contrast, the human-AI learning community's sense of purpose may be diminished, and a lack of performance may result from passively or mechanically adhering to AI's instructions, despite high levels of participation.

In conclusion, the literature does not reach a consensus on one side of the interaction, which shows that the comparison between human-human interaction and human-computer interaction in the context of second language acquisition is still a black box. In light of this, it is necessary to conduct further research to alleviate this ambiguity.

2.5. The Role of Artificial Intelligence (AI) in Foreign Language Learning

AI was roughly defined as “a collection of technologies that can solve problems and perform tasks to achieve defined objectives without explicit human guidance’’ (Healey, 2020, p.3). It offers numerous benefits such as offering adaptive learning (Li & He, 2020) and individualized learning environments (Luckin et al., 2016), opportunities for immediate response (Wang et al., 2022), lowering the inequivalence in language learning (Abernathy, 2024) by meeting the learners’ specific needs and

desires. UNESCO states that AI has the capacity to address significant obstacles in education, presenting novel opportunities for instructional methods and learning experiences within the classroom (UNESCO, 2021). Therefore, AI-driven tools have shown their potential to enhance the effectiveness of foreign/second language learning. Various AI-powered tools may be used in language learning to improve the four essential skills: reading, writing, speaking, and listening. Table 1 below displays some of the AI-driven tools.

Table 1. Often-used AI-driven tools

AI-Driven Tools	Skills Enhanced
Rosetta Stone	Enhanced listening comprehension skills (Kurniawan et al., 2021).
Grammarly	Enhanced writing skills of the language learners (Fitria, 2021)
ELSA Speak	Enhanced pronunciation and speaking skills of the students (Karim et al., 2023)
Duolingo	Enhanced vocabulary retention and grammatical understanding (Loewen et al., 2020)
BookBudy	Enhanced reading skills of the students (Ruan et al., 2019)
Quillbot	Enhanced writing and paraphrasing skills of the students (Xuyen, 2023)
Memrise	Enhanced vocabulary acquisition of the learners (Aminatun, 2019)
DeepL	Enhanced the learners' translation skills (Merkert, 2018)

This literature review will primarily examine the use of chatbots in foreign language education, since they are considered as novel and progressive tool that provides personalized (Ruan et al., 2019), interactive (Fryer et al., 2019), and engaging learning experiences (Lin & Chang, 2020), which are increasingly being recognized for their potential to enhance foreign language acquisition.

2.5.1. Chatbots and Foreign Language Education

Chatbots, also known as chatterbots, are software programs that simulate human-like conversations through text or text-to-speech functions (Caldarini, Jaf, & McGarry, 2022). These software systems have undergone substantial progress due to developments in AI technologies, including machine learning algorithms, natural language processing, and voice synthesis (Janarthanam, 2017). Chatbots can be traced back to ELIZA, a groundbreaking chatbot created in 1966 that imitated psychotherapist dialogues. ELIZA could be engaged by users via text input, and the chatbot would provide replies in return (Weizenbaum, 1966). The culmination of this development, alongside study findings (Berns et al., 2018; Fryer et al., 2017), underscores the substantial impact of chatbots in AI and HCI. Chatbots have been used in educational contexts since the early 1970s (Huang et al., 2022). However, their popularity in the field of education in English has significantly increased as a result of the advantages they provide to both students and instructors. Therefore, they caught the attention of the existing literature and language learners, educators since they offer customized learning experiences (Jia et al., 2012), provide immediate feedback which a human being may lack (Chen et al., 2023), availability anytime and anywhere (Garcia, Fuertes & Molas, 2018), and real-time interaction (Xu, 2020). Chatbots are also game-changing tools that are widely used in language practice. The research has shown that EFL learners practice their reading (Xu et al., 2021), listening (Fryer & Carpenter, 2006), writing (Guo et al., 2022), vocabulary (Kim, 2018), grammar (Kim et al., 2019), and speaking (Hsu et al., 2023). For example, Green and O'Sullivan (2019) conducted an extensive study on enhancing the spoken English language proficiency of 746 adult users of Liulishuo, an AI software designed for English learners in China, which operates in a similar manner to Duolingo. The results showed that nearly 72 percent of adult users improved in their test performance within approximately two months. Alongside the effectiveness of chatbots in the language learning context, they have shown their potential as a motivational ally for EFL learners. To illustrate, Wang et al. (2013) conducted experiments on chatbots, and it was discovered that they had beneficial effects on the motivation and engagement of language learners. Beyond their roles as motivating partners, they also have served as an effective tool to mitigate anxiety, a vital phenomenon in language acquisition, among language learners (Bao, 2019). Besides, Ismail (2020) conducted a study to

introduce an L2 chatbot that can detect and provide appropriate responses. His findings supported their role in diminishing the undesired feelings of learners. Furthermore, chatbots have been beneficial in alleviating shyness in language learners by providing a safe space for students to practice without the concern of assessment (Fryer & Carpenter, 2006).

Although chatbots have demonstrated their value in EFL settings, their limitations remain a subject of ongoing debate and research. A primary concern is their accuracy. Bowman (2022) highlighted this issue for language learners by stating that chatbots can provide answers to learners that appear impressive yet are entirely erroneous. Additionally, another concern arises from its absence of human traits. Chen et al. (2023) revealed that some of the students noted the incapacity of chatbots to fully mimic human emotions. Besides, Annamalai et al. (2023) investigated English language learning within the framework of self-determination theory. They reported that the learners had a lack of emotional attachment towards chatbots, which plays a fundamental role in the nature of learning a language. Apart from its lack of authenticity, the novelty effect of chatbots was mentioned to explain the reasons for the learners' short-term engagement (Fryer et al., 2019). As an illustration, Fryer et al. (2017) conducted a controlled study where they compared two sets of communicative activities. One set involved pairs of humans interacting with each other, while the other set involved pairs of humans interacting with chatbots. After 12 weeks of engagement, the level of interest in the task declined dramatically in the human-chatbot dyads, whereas there was no reduction found in the human-human partners.

ChatGPT, an AI-powered chatbot, is considered one of the most sophisticated in its field. Developed by OpenAI, a firm supported by Microsoft, it was launched in November 2022 (Kohnke et al., 2023). ChatGPT has been extensively utilized in EFL context due to its sophisticated natural language processing abilities and humanoid interaction (MacNeil et al., 2022). Baskara (2023) asserts that ChatGPT's capacity to produce text that resembles human language in response to input has the potential to captivate and inspire learners. The inherent linguistic possibilities of this tool enhance the authenticity and realism of writing practice. Exploring this area of language teaching is crucial as it can effectively sustain students' interest and motivation in EFL writing. According to Jeon and Lee (2023), ChatGPT can also enhance the teaching experience among teachers as it serves as an "interlocutor, content provider, teaching assistant, and evaluator" (p. 9). Apart from the learners, EFL teachers also consider

ChatGPT as a supportive tool for foreign language education. In this regard, Ulla et al. (2023) investigated the perspectives of teachers at universities in Thailand regarding the use of ChatGPT as a language teaching tool via an online interview survey, and teachers mostly expressed their positive attitudes towards it by highlighting its aid to enhance lesson planning and student engagement.

It could be argued that the incorporation of chatbots in EFL teaching has significantly influenced the learning environment by potentially providing more customized, readily available, and engaging learning settings. ChatGPT has played a vital role in EFL learning by enabling continuous support for the learners. However, as among the main drawbacks of chatbots, ChatGPT is also incapable of imitating human emotions, and has limitations related to accuracy which, in turn, leads to different approaches in the literature towards ChatGPT and chatbots (Chen et al., 2023) Therefore, these controversies underline the importance of continued research in the language education field since it is crucial to strike a balance between leveraging the strengths of AI-powered tools and addressing the nuanced needs of language learners.

In addition to these concerns, most studies investigating the role of chatbots in language acquisition have relied on methodologies such as t-tests, questionnaires, and surveys to assess their role in enhancing language learning, improving student motivation, and alleviating anxiety (Huang, Hew & Fryer, 2022). A recent study conducted by Hsu (2022) explored their role through a neuroscientific perspective by gathering data through NeuroSky Mindwave, a portable EEG device with fewer capabilities compared to traditional EEG devices. While this study offers valuable insights, there is still a need to further examine chatbots' impact from a neurocognitive perspective to better understand how they influence cognitive processes such as memory, attention, and emotional regulation during language learning interactions.

2.6. Electroencephalography (EEG) and Brainwaves in Foreign Language Acquisition

2.6.1. Introduction to EEG

As described by Britton et al. (2016), Hans Berger was the first to utilize the EEG to record brain activity from the human scalp, following its discovery by English physician Richard Caton, who obtained the first EEG from the open brains of monkeys and rabbits 140 years ago. This groundbreaking discovery laid the foundation for

modern neurophysiological research, allowing scientists to non-invasively study the brain's electrical activity in real-time. The EEG is a unique and essential assessment of the brain's electrical activity (Tatum & William, 2021). It is the process of recording electrical brain activity from the human scalp (Harmon-Jones & Amodio, 2012). The resulting recording is defined as "alternating electrical activity detected by metal electrodes and conductive media placed on the skull surface" (Teplan, 2002, p. 1). The EEG is capable of detecting changes on a timescale as short as one millisecond, which is remarkable given that it takes around 0.5-130 milliseconds for an action potential to travel across a single neuron, depending on the type of neuron (Niedermeyer & Da Silva, 2005; Teplan, 2002). Therefore, EEG has been considered a genuine "window on the mind" (Nunez & Srinivasan, 2006, p.2424). Moreover, it has been recognized as a psychophysiological measurement that is employed in research on brain-computer interfaces to investigate the connections between mental and physical processes (Nacke, Stellmach, & Lindley, 2010). Given the importance of the EEG as a crucial measurement in research, the positioning of electrodes is of great importance to provide precise and consistent data collection. The 10-20 electrode placement technique, which was adopted by the International Federation of Electroencephalography and Clinical Neurophysiology in 1958, established standards for electrode placement (Jasper, 1958; Teplan, 2002). This technique established a consistent placement and identification of electrodes on the scalp. As well as placement of the EEG, identification of artifacts generated by movements, blinks, sweating, and pulse (Sanei & Chambers, 2013) holds merit. After the data collection, a significant amount of time should be allocated to process the EEG data to eliminate contaminated data, ensuring that the resulting analysis reflects true neural activity rather than noise or interference (Bell & Cuevas, 2012). These processes play a crucial role in both clinical and experimental EEG applications.

2.6.2. EEG Oscillations and Cognitive States

The human brain contains around 86 billion neurons, and these neurons utilize neurotransmitters and electric impulses to initiate possible activities and communicate with one another (Azevedo et al., 2009). These signals are referred to as brainwaves (Cohen, 2017). Over several decades, extensive research has consistently demonstrated that neural oscillations, a fundamental characteristic of EEG recordings, are closely linked to various perceptual, cognitive, motor, and emotional functions

(Siegel et al., 2012). Electrical activity in the brain is believed to generate five wavebands (Noachtar et al., 1999; Başar,1999). These wavebands are alpha (α), beta (β), theta (θ), delta (δ), and gamma (γ) activities. Different cognitive processes are associated with oscillations of varying frequencies (Klimesch1999; Singer, 1999). The frequency, amplitude, and occurrence of brain waves are illustrated in Table 2. However, this section will focus specifically on alpha and theta activity, as these brainwaves are the primary focus of analysis in this study due to their established roles in cognitive and attentional processes.

Table 2. Brainwave Activity

Wave Type	Frequency (Hz) and Amplitude (μV)		Ocurrence
Alpha (α)	8-13	30-50	Produced in the parietal and occipital regions during rest or quiet states
Beta (β)	14-30	5-20	Occurs in the frontal region when alert or thinking; apparent during sensory stimulation
Theta (θ)	4-7	Less than 30	Occurs in the parietal and temporal regions during emotional pressure or deep relaxation
Delta (δ)	05-3	100-200	Mostly absent in conscious adults; occurs during deep sleep, unconscious states, or anesthesia
Gamma (γ)	31-50	5-10	Linked to selective attention, cognition, and perceptual activity

Source: Torres et al., 2020

2.6.3. Alpha and Theta Activity in Memory Processes and Relaxation States

The alpha rhythm, characterized by oscillations within an 8–13 Hz. range. Frequency range represents the most prevalent neural oscillation observed in the typical human EEG (Andreassi, 2007). Alpha activity typically becomes more pronounced during relaxed wakefulness, including periods of meditation, daydreaming, or simply when individuals close their eyes (Torres et al., 2020). However, alpha waves can significantly decrease when sudden alertness occurs or when the eyes are opened. They also decrease when alertness levels decrease, and drowsiness sets in (Pizzagalli, 2007). In the literature, alpha activity is predominantly associated with relaxation and calmness; however, studies have demonstrated its critical involvement in cognitive functions, including attention and motivation during cognitive tasks (Coan & Allen, 2004; Cooper et al., 2003; Hanslmayr et al., 2011; Knyazev, 2007; Palva & Palva, 2007), memory processes, particularly the transfer of information between short-term and long-term memory (Sauseng et al., 2002), and the regulation of visual sensory input (Romei et al., 2010).

Given the significant role alpha waves play in cognitive processes, it is crucial to explore how these waves relate to memory functions specifically. Memory, from a psychological and neurological perspective, refers to the accumulation of encoded neuronal connections within the brain. It refers to the process of reconstructing past events and behaviors by the simultaneous activation of neurons that were activated during the initial learning phase (Amin & Malik, 2013). The connection between alpha waves and memory is further reinforced by research showing that alpha activity is closely related to memory performance. Klimesch (1997) highlights that:

"...If we proceed from the idea that memory codes are retrieved via longitudinal pathways linking thalamic nuclei with the cortex, and that alpha is the predominant rhythm reflecting the activity of these pathways, we arrive at the hypothesis that alpha frequency should be related to memory performance. We have tested this hypothesis (Klimesch et al., 1990, 1993) and found that as compared to bad memory performers, good performers show a significantly higher alpha frequency." (p.320)

Additionally, Jensen et al. (2002) investigated the relationship between alpha-band power and memory load during short-term memory retention tasks. They demonstrated that alpha power systematically increased with the number of items maintained in working memory.

Beyond alpha activity, frontal theta activity observed during wakefulness has also been associated with attention, cognitive effort, memory processes, emotional regulation, and the processing of meaningful stimuli (Knyazev, 2007; Pizzagalli, 2007). The research has examined the correlation between theta activity and memory and has demonstrated that memory demands resulted in an increase in theta band power (Klimesch, 1999; Jensen et al., 2002). For instance, Burgess and Gruzelier (2000) examined memory-related alterations in the EEG using words and faces as stimuli and discovered an increase in theta range. Theta activity is informative not only about memory processes but also about states of meditation and relaxation. Theta power is higher in meditative states, according to numerous investigations in the literature (Aftanas & Golocheikine,2001, 2002; Banquet, 1972, 1973; Lagopoulos et al., 2009). In addition, theta power is elevated in the frontal and central regions of the brain during periods of relaxation (Baijal & Srinivasan, 2010; Jacobs & Lubar 1989; Pagano & Warrenburg, 1983).

Therefore, measuring fluctuations in alpha and theta neural oscillations can reveal aspects of participants' information processing states, even when the participants themselves are unaware of these changes or unable to articulate them verbally (Basar, 1999; Klimesch et al., 2005). Alpha and theta activities can offer valuable insights into a variety of mental states. While alpha waves are primarily associated with memory processes, attentional regulation, and relaxation, theta waves provide supplementary information about deeper cognitive functions, including memory encoding, retrieval, and emotional regulation. The combined analysis of alpha and theta activity, particularly in the frontal and temporal regions, can be essential for comprehending cognitive load, mental effort, and relaxation states during tasks.

2.6.4. The Usage of EEG in EFL Education

EEG has been widely used in clinical research to diagnose epilepsy (Sanei & Chambers, 2013; Smith, 2005), sleep disorders (Beebe et al., 2010; Kupfer et al., 1978), attention-deficit/hyperactivity disorder (Gola et al., 2013), evaluate mental exhaustion (Lianyi et al., 2010), and assess emotions (Zhang et al., 2011). However, it has been rarely utilized in educational research even though EEG applications offer high temporal resolution, plasticity, brain mapping, and ease of use (Amin & Malik, 2013). Scholars employ it to investigate brain activities associated with diverse cognitive processes such as attention, perception, and memory, as it offers valuable

information on the interactions between different brain regions during these processes (Cohen, 2017). For example, a study conducted by Liu et al. (2013) investigated how EEG technology could be utilized to measure students' attention. Besides, in 2001, Gerlic and Jausovec conducted a study to investigate alpha activity and its variations in EEG signals between novice and experienced teachers, as well as between teaching courses that utilize textual materials versus multimedia resources.

In the realm of language acquisition, it is infrequently used in research, mostly in studies focused on bilingualism. To illustrate, Momenian et al. (2024) employed an EEG device to investigate whether bilingualism affects the electrophysiological substrates of language prediction. Besides, scholars have sought neural responses during the process of learning a new language by observing through EEG recordings (Soman et al., 2019). Apart from the traditional EEG, some of the researchers in the language acquisition field used portable EEG devices, such as those developed by NeuroSky. Although they provide a more accessible and cost-effective option for certain studies, especially in naturalistic or non-laboratory settings, these portable devices offer fewer functionalities and lower resolution compared to traditional EEG systems. These devices were utilized to investigate reading (Chen & Huang, 2014), attentiveness (Liu et al., 2013), game-based learning techniques (Ghergulescu & Muntean, 2016), students' positive emotions (Huang et al., 2017). For example, Chen and Huang (2014) applied the MindSet earphone developed by NeuroSky, which tracks attention levels through EEG signals to enhance learners' sustained attention and reading performance. Besides, Ghergulescu and Muntean (2016) analyzed EEG data from the Emotiv EPOC headset, one of the portable EEG devices, to provide valuable insights into the incorporation of game tasks to support personalization of learning experiences. Additionally, Huang et al. (2017) investigated whether the use of humorous images as rewards for correct answers in class can improve students' positive emotions, attention levels, learning confidence, and test scores by employing NeuroSky MindWave. Despite the fact that these studies provided valuable insights into the field of language acquisition from a neuroscientific perspective by utilizing EEG devices, the utilization of EEG technology for gathering neural data on simultaneous production, such as speaking and listening, remains a black box that requires further investigation. Nevertheless, EEG has already demonstrated potential as a reliable tool for assessing speech production (Hagoort & Van Turennout, 1997). Accordingly, Calliess (2006) emphasized that despite current challenges, EEG holds

promise for future research into assessing internal speech processes. Similarly, Adjouadi et al. (2004), in their study, demonstrated EEG's potential for use in assessing speech production.

While the existing body of research has extensively examined the role of interaction in foreign language teaching, particularly in comparing human-human interaction and human-computer interaction, significant gaps remain in understanding the underlying cognitive and emotional processes involved. Numerous research predominantly depends on self-reported data or behavioral results, offering a limited comprehension of the real-time brain mechanisms underlying language acquisition. Neurophysiological technologies like EEG, capable of providing accurate and real-time monitoring of brain activity, have been insufficiently employed in this context. The majority of EEG studies in language learning have concentrated on tasks such as vocabulary retention and attention, although they seldom examine communicative behaviors crucial for language acquisition, including speaking and listening. Moreover, there is a distinct lack of studies comparing HHI and HCI in second language acquisition from a neurophysiological perspective.

This study also seeks to address the significant gap by potentially being among the first to directly compare different interaction types (e.g., HHI and HAI) in foreign language acquisition through the lens of EEG data. It will offer valuable insights into the role of alpha and theta brainwave activity during English-speaking tasks, and emphasize critical cognitive processes including memory, emotional regulation, and relaxation. By measuring these brainwave activities, the research aims to explore the variation between HHI and HAI in language settings. This method will not only enhance the comprehension of the impact of interaction type in foreign language acquisition, but it also introduces a neurophysiological dimension in language research. Ultimately, the study's findings aim to bridge the gap between cognitive neuroscience and language education by offering a more comprehensive understanding of the neural mechanisms underlying various modes of interaction in language learning environments.

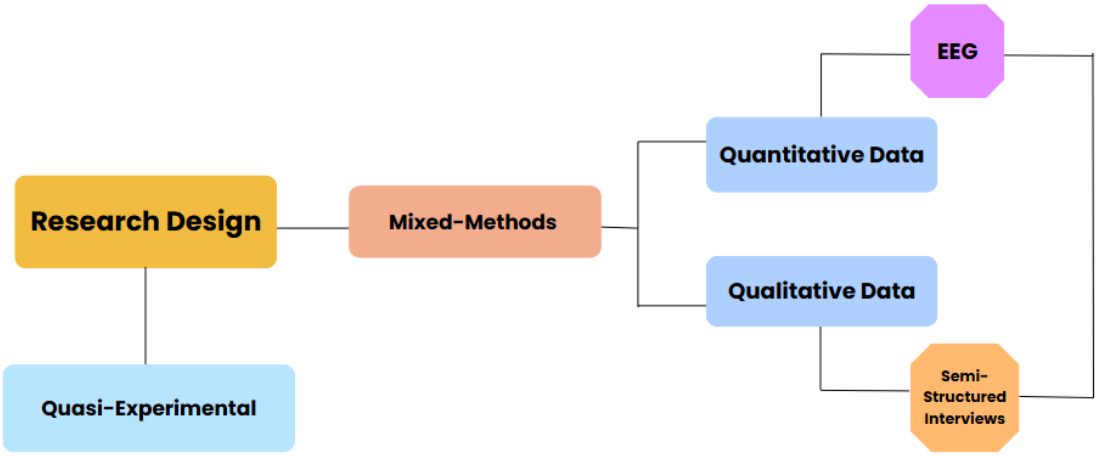
3. METHODOLOGY

3.1. Research Design

This study investigated neurological and cognitive processes associated with English speaking tasks under two interaction conditions: human-human interaction (HHI) and human-computer interaction (HCI), the latter involving AI-mediated chatbots. The research followed a quasi-experimental design within a mixed-methods framework, integrating both behavioral and neurophysiological data to gain a multifaceted understanding of language interaction. The research employed EEG as the primary instrument for capturing neural activity, due to its high temporal resolution and sensitivity to cognitive and linguistic processes. Therefore, the primary focus was to examine the brainwave data through EEG recordings to compare potential neural differences between the two interaction conditions during spontaneous English speech production.

In addition to the quantitative EEG data, semi-structured interviews were conducted to gain insights into the participants' perceptions of the interaction conditions. The qualitative data were specifically collected to triangulate with quantitative data and to offer deeper contextual understandings of quantitative EEG data. An overview of the research design is provided in Figure 2.

Figure 2. The Research Design



This study adopted a mixed-methods approach to integrate both quantitative EEG data and qualitative data, which is a pervasive phenomenon in the social and educational sciences (Creswell, 1999). Mixed-method design enables researchers to combine both quantitative and qualitative methods to provide a comprehensive understanding of phenomena (Creswell & Clark, 2017). Tashakkori and Creswell (2007) defined mixed-methods design as "research in which the investigator collects and analyzes data, integrates the findings, and draws inferences using both qualitative and quantitative approaches or methods in a single study or program of inquiry" (p. 4). While qualitative methods provide detailed analysis about participants' experiences, beliefs, and emotions, quantitative methods offer acceptability, validity, and generalizability of the findings, which holds merit to comprehend the multifaceted nature of human behavior (Hanson et al., 2005; Johnson & Onwuegbuzie, 2004). It furnishes researchers with a flexible and adaptive research design rather than adhering strictly to methodological purism (Tashakkori & Teddlie, 2010). Therefore, the research aims to be equipped with a more nuanced understanding of the investigation.

The primary quantitative data were obtained through EEG recordings, a non-invasive method that captures neural responses (Niedermeyer & da Silva, 2005). To complement the quantitative findings, semi-structured interviews were conducted as qualitative data to explore participants' perceptions of their experiences with the two interaction contexts, with the ultimate aim of triangulating the quantitative data. This is aligned with Denzin's (1970) perspective, who identifies triangulation as "combining multiple observers, theories, methods and data sources (so that researchers

can) overcome the intrinsic bias that comes from single methods, single-observer and single-theory studies" (p. 313). He further emphasized the value of triangulation by highlighting its importance in alleviating the complexity of social phenomena (Denzin, 2012). With EEG data and interview responses, the study aimed to cross-validate the results.

The design was considered quasi-experimental due to the non-random assignment of participants to interaction conditions, while still adhering to controlled experimental procedures (Campbell & Stanley, 2015). Participants were assigned to either the HHI or HCI condition based on their availability and willingness to participate, a method consistent with quasi-experimental principles that prioritize group matching over randomization (Campbell & Stanley, 1963). While the HCI group engaged with an AI-mediated tool, ChatGPT, in English-speaking tasks, the HHI group interacted with a human instructor. To control extraneous variables and enhance internal validity, as Campbell and Stanley (1963) suggested, homogeneity in key characteristics such as English-speaking proficiency levels, age, and neurological health was ensured.

This study was also classified as clinical research since it heavily relied on EEG technology to record and visualize brain activity and was conducted in a controlled clinical environment. In clinical research, according to Babiloni et al. (2020), brain activity is recorded from the subjects' scalp under open- or closed-eye conditions. Additionally, as the International Federation of Clinical Neurophysiology (IFCN) suggests, EEG recordings should be performed in a controlled environment (Nuwer et al., 1994). Data collection was conducted in a fully equipped hospital under the supervision of a neurologist, ensuring the precision and reliability of the EEG recordings. The clinical environment provided standardization of EEG procedures, which are aligned with IFCN recommendations and the Declaration of Helsinki.

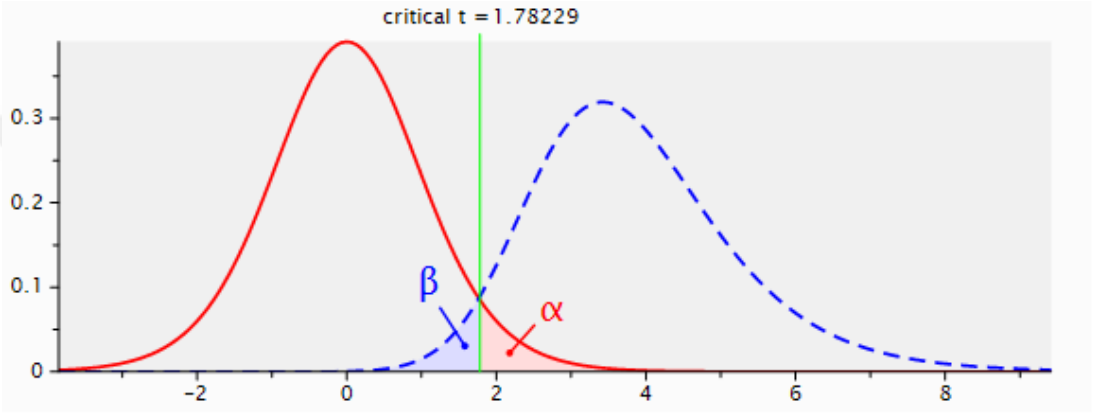
3.2. Participants

3.2.1. Population and Sample

The population for this study comprised undergraduate students enrolled in the English Language Education department who were within a similar age range, demonstrated comparable English proficiency levels, and had no known neurological conditions. From this population, the sample included 37 undergraduate students from the English Language Education department at Yıldız Technical University in İstanbul.

The sample size was calculated using the Power Analysis method via the G-Power 3.0 software, based on the effect size (η2= 1.00) and confidence interval (p <0.05) reported in a prior study by Hsu, L. (2022), along with a beta value (β: 0.095). By inputting the effect size (η2= 1.00), confidence interval (p <0.05), and beta value (β: 0.095) into the G-Power program, the resulting sample size calculation produced the graph shown below (graph 1). According to this graph, the minimum required sample size was determined to be a total of 26 participants, with 13 in the HCI group and 13 in the HHI group.

Graph 1. Size Calculation



Although the initial sample size was determined to be a total of 26 participants—13 in each condition, based on a G*Power analysis, this study ultimately included 37 participants: 20 in the HCI group and 17 in the HHI group. Initially, a total of 40 participants were planned, with an equal distribution of 20 participants per group. However, some participants were excluded from the study due to unavailability during the data collection period. This slight imbalance did not compromise the representativeness of the groups or lead to any statistically significant differences; therefore, the study proceeded with 17 participants in the HHI group. The increase beyond the minimum sample size was intentional to account for potential participant attrition, often referred to as participant mortality, which can negatively impact the validity and generalizability of research findings. As Cohen (2016) emphasizes, an adequate sample size is essential for achieving sufficient statistical power and for supporting the broader generalization of results. This adjustment was made to maintain the integrity of the study's outcomes despite minor dropout or exclusion.

In this study, the participants were selected through convenience sampling. Convenience sampling, also referred to as haphazard or accidental sampling, is a

nonprobability sampling method where participants are selected based on practical criteria such as ease of access, geographical proximity, availability at a specific time, or willingness to participate (Dörnyei, 2007).

3.3. Inclusion and Exclusion Criteria

When determining the sample for the study, several inclusion and exclusion criteria were meticulously applied. The participants who were available and willing to participate in the study were selected in the study, taking their convenience and their consent to participate in the study voluntarily into consideration. According to Patino and Ferreira (2018), this is one of the fundamental factors in the studies when selecting the participants. In alignment with the recommendation in the literature (Tholen, Francis, & Chappel, 2006), individuals in the same age group were determined to be included in the study to maintain homogeneity among study participants. Besides, participants should not have any neurological illnesses such as epilepsy or learning disabilities, which was a critical parameter in the study. This exclusion criterion was vital to eliminate confounding variables that could affect cognitive processing and language acquisition (Lezak et al., 2012; Schaeverbeke et al., 2021). To ensure this, a neurologist conducted clinical assessments to confirm the absence of neurological disorders before participation. Following the initial selection, an English language speaking proficiency test was administered to ensure participants had approximately the same proficiency level, an essential step for creating a baseline for comparison. Assessing an initial English speaking proficiency level among the participants is highlighted in the literature as a crucial step in language studies (Oller, 1979).

The proficiency test administered in this study was the speaking module of a sample International English Language Testing System (IELTS) test, which comprises three parts. In the first part, participants discussed topics such as their hometown, aiming to assess general speaking ability. The second part involved a task card requiring participants to speak for 2-3 minutes on a given topic. The final part included further questions related to the second part, with participants expected to elaborate for 4-5 minutes.

3.4. Demographic Information

Demographic information about the participants was gathered using Google Forms prior to conducting the study. The demographic details of the 37 participants are outlined along with their IELTS speaking proficiency results in Table 3. The sample consisted of 20 participants in the HCI group and 17 in the HHI group. The collected data included age, gender, and level of education.

The majority of participants (n=25) reported having proficiency in English solely as a second language, while a smaller group (n=12) spoke multiple languages. The majority of participants (n=33) were right-handed, with a minority (n=4) being left-handed. Additionally, all participants had prior experience with ChatGPT. The majority (n=32) used it for instructional purposes, while a smaller subset (n=5) used it for casual chatting. Finally, most participants (n=35) reported feeling comfortable when interacting with ChatGPT.

Table 3. Demographic Information of the Participants

Variable	**HCI group (n=20)**	**HHI group (n=17)**	**Total (n=37)**
Age Range	18-24	18-24	18-24
Mean Age	20	20	20
Gender			
- Male	6	3	9
- Female	14	14	28
Educational Level	Undergraduate	Undergraduate	Undergraduate
Speaking Proficiency Level (IELTS)			
- Mean IELTS Band Score	7.63	7.37	7.50

3.5. Recruitment Process and Ethical Considerations

Given that the current study is grounded in clinical research, ethical approval for this study was obtained from the Altınbaş University Health Sciences Scientific Research Ethics Committee on May 30, 2024, during meeting no. 7, under document number

69534. (see Appendix 1). In addition, since the study involved participants from Yıldız Technical University, ethical approval was also obtained from the Social Sciences Institute of Yıldız Technical University under document number 006524 (see Appendix 2).

Besides, it is important to take into account certain concerns and criteria as outlined by the World Medical Association. This organization issued a set of recommendations known as the Declaration of Helsinki in 1964 (Williams, 2008). The Declaration of Helsinki (DoH) is an internationally recognized ethical guideline for conducting medical research. It was officially approved by the World Medical Association (WMA) General Assembly in 2009 (Puri et al., 2009).

DoH offers extensive ethical principles for the execution of medical studies involving human participants. The principle of individual autonomy is emphasized, necessitating informed consent to ensure that participants are fully aware of the study and willingly choose to take part. Scientific validity is of utmost importance, necessitating that those investigations be grounded in comprehensive information and endorsed by an impartial ethics commission. The DoH also emphasizes the significance of upholding the privacy and confidentiality of participants. It requires researchers to disclose study findings and grant access to helpful therapies after the study.

To ensure compliance with the DoH, specific actions were taken during the research procedures. Recruited participants were informed about the details and purposes of the study in person. Prior to participant selection, an informed consent form was prepared (Appendix 3), containing details about the study's purpose, procedures, and ethical considerations. Additionally, participants were informed about the use and implications of the EEG device. During this informational session, participants had the opportunity to ask questions and address any concerns. Those who expressed willingness to participate were provided with informed consent forms, ensuring they comprehended their rights and the voluntary nature of their involvement. This process was designed to ensure that the study would be conducted transparently and adhere to ethical standards.

3.6. Materials

3.6.1. Description of Instruments

In the study, EEG was employed to analyze participants' brainwaves. EEG is a pervasive and non-invasive technique that measures the brain's electrical activity to gain a better understanding of neural processes and cognitive functions. This technique captures the electrical signals produced by neurons in the brain. These signals are detected through electrodes placed on the scalp, providing a record of the brain's electrical activity. (Niedermeyer & da Silva, 2005). By recording and analyzing these signals, EEG enables the assessment of cortical functioning in real time.

In 1958, the International Federation of Electroencephalography and Clinical Neurophysiology introduced the 10-20 electrode placement system. This system established a standardized method for positioning electrodes on the scalp (Jasper, 1958; Teplan, 2002). It organizes electrode locations by dividing the head into proportional distances based on key skull landmarks (nasion, inion, and preauricular points) to ensure thorough coverage of all brain areas. The "10-20" terminology reflects the proportional distances, measured in percentages, between the ears and the nose, where the electrode sites are selected. Electrode placements are designated according to the adjacent brain regions: F (frontal), C (central), T (temporal), P (parietal), and O (occipital). The standard EEG setup comprises 21 electrodes, including 19 active electrodes and 2 reference (ground) electrodes. Each electrode is carefully positioned on the scalp to capture electrical activity from different brain regions. Accurate electrode placement is essential for effectively recording and interpreting brain activity.

Therefore, it is important to emphasize the purpose of each electrode and what specific brain activity it measures, as specified in Table 4.

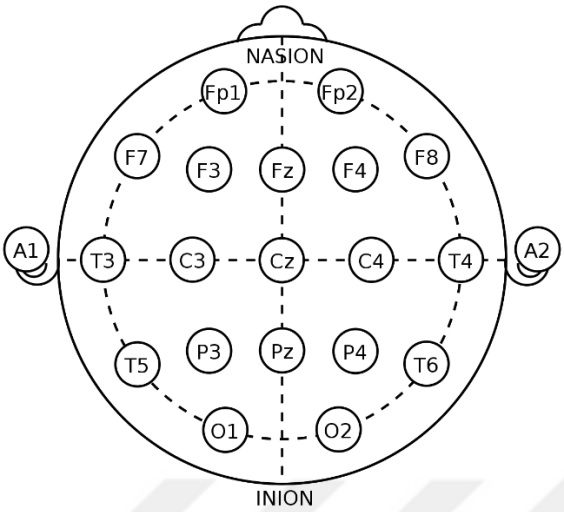
Table 4. EEG Electrodes Placement

Electrode Group	Electrodes	Location	Functions Monitored
Frontal-Polar Region (Fp)	Fp1, Fp2	Forehead near the frontopolar area	Attention, planning, voluntary movement functions
Frontal Region	F7, F3, Fz, F4, F8	The front part of the brain	Cognitive abilities, personality traits, and motor functions
Temporal Region	T3, T4, T5, T6	Over the temporal lobes	Auditory functions, memory, emotions
Central Region	C3, Cz, C4	Central part of the scalp	Primary motor cortex, voluntary muscle movements
Parietal Region	P3, Pz, P4	Over the parietal lobes	Sensory perception and integration
Occipital Region	O1, O2	Over the occipital lobes	Visual processing

Source: Russell-Chapin et al., 2020

The figure below (Figure 3) illustrates the proper placement of electrodes on the scalp according to the International 10-20 System.

Figure 3. Electrode Placement on the Scalp According to the International 10-20 System



Source: Russell-Chapin et al., 2020

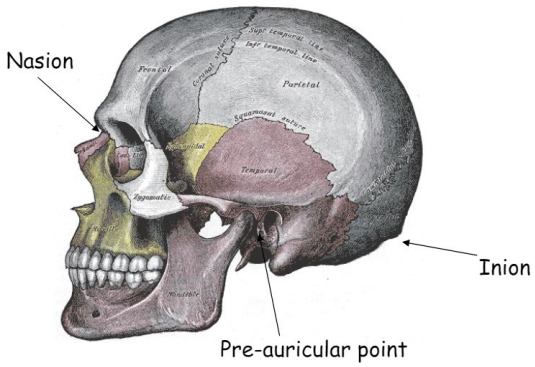
The placement of the EEG device

The 10-20 system, introduced by Jasper in 1958, is widely used for placing EEG electrodes and linking external skull locations to underlying brain areas. This system relies on identifying key anatomical landmarks such as the nasion, inion, and preauricular points, and placing the electrodes at fixed intervals of 10% or 20% of the total distance between these points, accommodating different head sizes (Morley, Hill, & Kaditis, 2016).

In the study, electrodes were positioned on the scalp following measurements based on the 10-20 placement system. Initially, reference points on the head, such as the nasion, inion, and preauricular points, were identified (as shown in Figure 4). The distance between the nasion and inion is measured, and 10% of this distance is marked upwards from the nasion. Moving further in the same direction, 20% of the distance is marked from the previous point, and the endpoint will be 10% above the inion. These intervals mark the Fz, Cz, and Pz points along the midline.

The fourth step involves identifying points between Fp1-O1 and Fp2-O2, specifically F3, C3, P3, F4, C4, and P4. The midpoint between Fp1 and O1 is C3; halfway between Fp1 and C3 is F3; halfway between C3 and O1 is P3. For example, 10 cm back from Fp1 is F3, and 10 cm back from C3 is P3. This process is mirrored on the right side of the head to determine F4, C4, and P4.

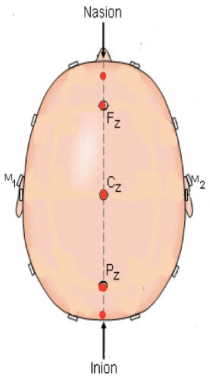
Figure 4. Reference Points: Nasion, Inion and Pre-auricular Point



Source: Morley, Hill & Kaditis, 2016

The nasion is the dip between the eyes above the nose, and the inion is the bump at the back of the skull. The tape measure is placed at the nasion, and the participant tilts their head forward to extend the tape to the inion. Following this, electrode placement starts. Points along the midline from front to back of the head are established, specifically Fp, Fz, Cz, and Pz (Figure 5).

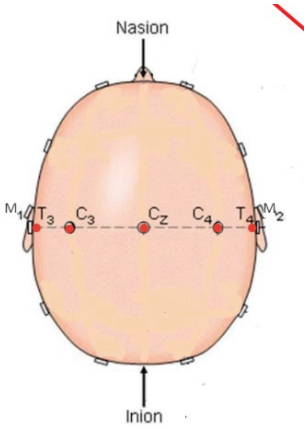
Figure 5. Fp, Fz, Cz, and Pz Placement



Source: Morley, Hill & Kaditis, 2016

The next step involves identifying the electrode points that will be aligned between the ears. These electrodes include T3, C3, C4, and T4 (Figure 6). To do this, the distance between the front edges of both tragi is measured, passing through the Cz point. From both tragi, 10% of this distance is marked in the same direction. This process establishes the positions of the C4 and T4 electrodes on the right side of the Cz point, and the C3 and T3 electrodes on the left side.

Figure 6. T3, C3, Cz, C4 and T4 Placement

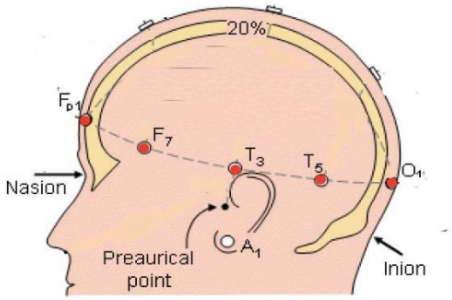


Source: Morley, Hill & Kaditis, 2016

The third step involves determining the placement of electrodes around the head horizontally. The electrodes involved are Fp1, Fp2, F7, F8, T3, T4, T5, T6, O1, and O2 (Figure 7.). To do this, the circumference of the head is measured, passing through the points that are 10% above the nasion and inion, as well as T3 and T4. From this measurement, 10% of the value is taken. Half of this length is marked to the left of the Fpz point, and the other half to the right, identifying the Fp1 and Fp2 electrode positions. Moving 10% from these points towards T3 and T4 locates the F7 and F8 electrodes. Continuing in the same direction, the next 10% marks the T3 and T4 positions, and the last 10% towards the back identifies the O1 and O2 electrodes. The distance between O1 and O2 is also 10% of the head circumference, similar to the distance between Fp1 and Fp2. The points 10% away from O1 and O2 towards T3 and T4 determine the T5 and T6 electrode positions. In the fifth step, all intersections are finalized. Points F3, F4, P3, and P4 are reassessed laterally. The Fz point and the midpoints between F7 and F8 form the standard positions for F3 and F4, while the Pz point and the midpoints between T5 and T6 form the standard positions for P3 and P4. This process identifies a total of 19 electrode points on the head.

Following the international 10-20 system, the Fp2 and Fp1 electrodes are usually placed near the eyes, while T3 and T4 are located close to the ears. To reduce the risk of muscle artifacts caused by participants' speech in our study, we have modified these placements. Fp2 and Fp1 are now positioned above the eyes, and T5 and T6 are placed slightly higher than the ears. This adjustment is essential to avoid potential muscle artifacts that could compromise the quality of our data.

Figure 7. Fp1, F7, T3, T5, O1, O2 Placement

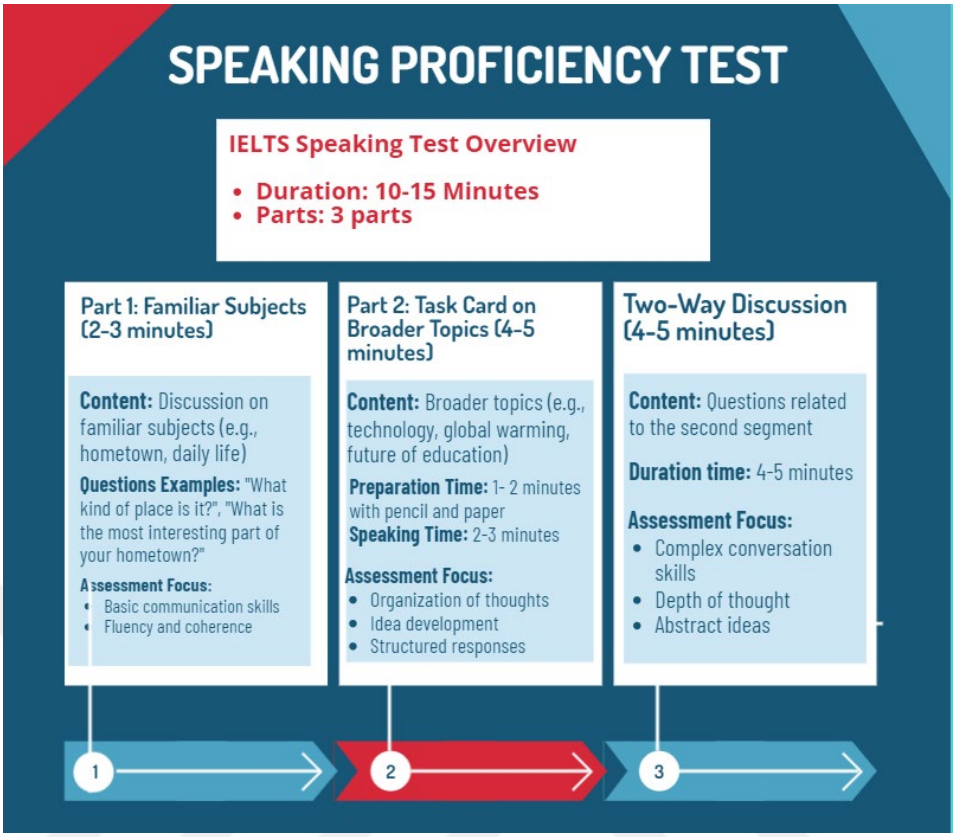


Source: Morley, Hill & Kaditis, 2016

English speaking proficiency test

To evaluate the participants' English-speaking skills, a sample IELTS speaking test was conducted, mirroring the actual exam's comprehensive standards. The test consisted of three parts, lasting about 10-15 minutes in total (Figure 8). In the first part, participants discussed familiar subjects like their hometowns or villages, answering questions such as "What kind of place is it?" and "What is the most interesting part of your hometown?" This segment, about 2-3 minutes long, assessed their ability to communicate basic information about themselves and their daily lives, focusing on general speaking skills, fluency, and coherence. The second part involved a task card on broader topics like technology, global warming, or the future of education. Participants had one minute to prepare their response using a pencil and paper, then spoke on the topic for 1-2 minutes, addressing specific questions posed by the examiner. This segment tested their ability to organize thoughts, develop ideas, and provide detailed, structured responses within a limited time. In the final part, participants answered additional questions related to the second segment, engaging in a two-way discussion with the examiner for 4-5 minutes. This part evaluated their ability to participate in a more complex conversation, demonstrating depth of thought and discussing abstract ideas. This structured approach ensured a thorough assessment of the participants' English-speaking proficiency, covering both everyday and complex topics, reflecting the IELTS speaking test's format and rigor. Additionally, the examinations were recorded to allow for later review and analysis to ensure accuracy and consistency in scoring.

Figure 8. English Speaking Proficiency Test Design



Scores were assigned using a standardized rubric, specifically the IELTS speaking scoring rubric. This detailed rubric assesses four main components: fluency and coherence, lexical resource, grammatical range and accuracy, and pronunciation. Each component is rated on a scale from 1 to 9, with 1 indicating non-user proficiency and 9 indicating expert proficiency.

Fluency and Coherence: This criterion evaluates the participant's ability to speak smoothly without excessive pauses and to logically organize their thoughts. Evaluators look for a smooth flow of speech and appropriate use of cohesive devices to link ideas (IDP IELTS, 2023).

Lexical Resource: This criterion assesses the range and appropriateness of the vocabulary used. It includes the use of less common and idiomatic vocabulary, as well as the ability to paraphrase effectively when necessary (British Council, 2023).

Grammatical Range and Accuracy: This aspect evaluates the variety and correctness of grammatical structures. Evaluators consider the correct use of both simple and complex sentence structures and the frequency of grammatical errors.

Pronunciation: This criterion examines how easily the participant can be understood, including correct use of intonation, stress, and rhythm. It assesses the clarity of pronunciation and the ability to use pronunciation features to enhance meaning (IDP IELTS, 2023).

To ensure the evaluations' reliability and accuracy, both the researchers and an independent rater conducted the assessments. This practice, known as inter-rater reliability, helps to minimize subjective bias and ensures consistent and fair scoring across different evaluators. This approach is supported by established literature in language assessment, emphasizing the importance of standardized scoring methods and inter-rater reliability (Bachman & Palmer, 1996; Brown, 2018).

Semi-Structured Interviews

To delve into the participants' opinions on their experiences with the study, semi-structured interviews were conducted with participants face-to-face, which facilitated insights into the participants' perceptions. Semi-structured interviews are employed in the studies as a data collection method aimed at interpreting the participants' unique perspectives instead of a broad understanding of a phenomenon (McGrath et al., 2018). The present study implemented semi-structured interviews to gather information from the participants about the nature of the study, which has distinctive aspects such as the implementation of the EEG device, interaction with a human instructor, and interaction with ChatGPT. Aligning with the recommendations from the literature (Creswell, 2008), it was determined that it would be pertinent to inquire into the participants' opinions on their experiences with producing English language speaking through human interaction and ChatGPT interaction.

Considering the purposes of the study, both sampling groups, consisting of HCI and HHI groups, received different open-ended questions due to the variance in their interaction. To ensure the reliability of the questions, two experts from the Yıldız Technical University were consulted. Approved questions by experts were finalized to collect information from the participants.

The HCI was asked to provide insights on five questions regarding their experiences with ChatGPT about their language practice. Besides, the HHI group was also required to articulate their perspectives on five questions, including their experiences with a human instructor in English language speaking practice. The questions were formulated in alignment with the aim of the study to reveal the participants' perceptions

of the study. The interviews were carried out in English and conducted face-to-face, with oral recordings made following participant consent to be reviewed and transcribed later for the analysis.

3.7. Procedure

3.7.1. Preparation

The research procedures complied with the Declaration of Helsinki. Given that the study possessed the uniqueness regarding the device employed, the participants were assured that the study did not include any detrimental effects on their health and was devoid of any pain-inducing features, which were primary concerns. The participants were also notified that EEG recordings would be conducted under the supervision of a neurologist, with whom they could consult any confusing questions, as written on the informed consent form. The participants' prior knowledge of the concept of EEG devices from their Second Language Acquisition course at Yıldız Technical University facilitated the study (Yıldız Technical University, n.d.). Group chats were set up on WhatsApp, providing an expedited communication environment between the participants and the researchers, where they could also ask additional questions, such as the location of the hospital where the study was carried out, the timeline, etc.

3.7.2. Data Collection

Regarding the multi-layered nature of the study, the data collection process is composed of various stages, each of which warrants a detailed explanation.

First, in order to conduct the study, the permissions from the hospital and ethical committee, an essential aspect of the studies (De Wet, 2010) were granted.

The scope of the study necessitates proficiency in operating the EEG device, it was vital to provide the researcher with training. Therefore, the researcher was provided with instruction regarding the purpose and functioning of the EEG device. The training provided by a professional neurologist in the field to the researcher lasted 3 weeks as a consequence of the complexity of the function of EEG device.

3.7.2.1. Researcher Training

During the initial week, the training session encompassed the introduction of the EEG device. The neurologist explained the functionality, purpose, and research applications

of EEG devices. In addition, a comprehensive explanation was provided regarding the electrodes, including each of their functions and the specific measurements they are capable of obtaining. Additionally, the software Neuron-Spectrum.NET was introduced. This software is designed to perform EEG exams using the digital EEG and EP systems from the Neuron-Spectrum series, manufactured by Neurosoft Ltd. It also allows for the analysis of recorded EEG data and the generation of reports. The system connects to the EEG device, managing electronic signals and providing comprehensive insights into brainwaves, collected data, and video recordings during the session.

The second week included a lecture on the placement of the EEG device, a critical aspect of the study, as each electrode must be precisely positioned on the scalp. This task demands a meticulous approach. The researcher received training on the International 10-20 placement system and was instructed on the positioning of EEG electrodes on a human head model. This segment also covered the steps involved in electrode placement, demonstrated by the professional body, which included the use of various tools such as abrasive paste, alcohol wipes, and measuring tape.

The third and the last week was implementation week when the researcher was instructed to position the electrodes without any outside help on a scalp. Besides, the researcher required to follow the skin preparation steps before applying the electrodes on the scalp. The process included measuring the placement of electrodes and applying them to the scalp using paste, adhesive, and measuring tape. In this session, the researcher also checked the amplifier to ensure the placement of the electrodes was appropriate.

3.7.3. Participant Preparation

The participant preparation phase is essential to ensure the accuracy and reliability of the EEG data collected during the study. Proper preparation helps minimize artifacts and ensures that participants are comfortable and informed about the procedures.

Prior to the study, the participants were informed of the location of the hospital via group chats, and they were requested not to use any hair products such as gel or spray. Upon arrival at the hospital, they were asked to read the hard copy of the informed consent form and sign it to confirm that they had attended the study based on their willingness to participate in the study as a volunteer. The participants were escorted to the room where the EEG device was set up and ready to record, and given time to have

a look at the place to feel more comfortable and be accustomed to the environment. Before the placement, instructions were provided on how to remain still and relaxed during the recording to minimize movement artifacts. Even though they had prior knowledge of the design of the study, consisting of whether interacting with the human or ChatGPT, the design was reviewed again to remind them of the process.

After the briefing, the skin was prepared for the recording. The skin preparation process started with the cleaning of the surface of the scalp with isopropyl alcohol wipes, removing the grease and dead skin cells that could interfere with electrode adhesion. After cleaning, the researcher carefully measured and marked the electrode sites on the participant's scalp, using the International 10-20 System. Electrodes were then attached using a conductive paste to ensure good contact (Figure 9). The researcher verified the proper positioning of the electrodes by examining the lights on the amplifier. If the electrodes were correctly attached to the scalp, the lights on each electrode would change from red to green. Throughout the study, measures were taken to ensure the participants' comfort and safety. Participants were provided with a comfortable chair and were encouraged to communicate any discomfort or concerns immediately.

Figure 9. Electrodes Placement



3.7.4. Data Collection Sessions

After the electrodes had been securely placed on the scalp, the participants were asked to select randomly one of the topics from the box containing topics such as describing a perfect day, sharing future aspirations, etc. These tasks were structured to promote prolonged English-speaking sessions in order to ensure more effective and stable EEG data collection since an optimal 20-25 minute recording time was required.

These tasks were presented as a list below:

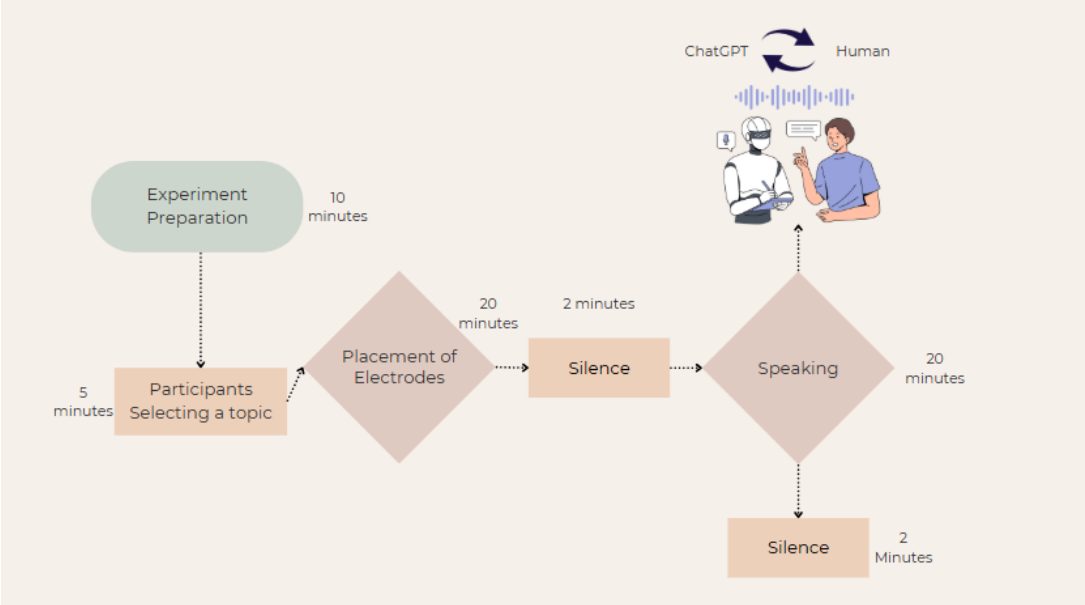
1. Describe Your Perfect Day: Ask participants to describe their perfect day from morning to night. Encouraging them to be detailed about locations, activities, people they would be with, and why these elements contribute to their perfect day.
2. Travel Experience: Participants discuss a memorable travel experience. They should mention where they went, what they did, what stood out about the culture, and any interesting interactions with locals.
3.A Significant Life Event: Participants reflect on a significant event in their life (e.g., graduation, a particular achievement, or a family event) and talk about how it impacted them personally and professionally.
4. Future Aspirations: Asking participants to discuss their future aspirations. They can describe their ideal job, where they would like to live, and what personal or professional goals they aim to achieve in the next five years.

The HHI group was informed that they would discuss the selected topic with the instructor in English, and the HCI group was given instructions to engage with ChatGPT about the selected topic in English. The HCI group received a concise explanation on how to provide prompts to ChatGPT in order to generate further English responses. The prompts consisted of the phrase “I am going to discuss...” “Could you kindly provide brief responses and ask questions to sustain the conversation?” Following the briefing, the participants were instructed to remain still and refrain from any physical movements to minimize muscular artifacts. The process of data collection for the HCI group is illustrated in Figure 10. In addition, they were provided with guidelines for the recording session, which entails 2 minutes of silence, followed by 20 minutes of English real-time speaking, and concluding with another 2 minutes of silence, resulting in a total duration of 24 minutes. The process of the data collection of the HCI group is given in Figure 11, which illustrates the process with duration.

Figure 10. The HCI Group Data Collection



Figure 11. The HCI Group Data Collection Process

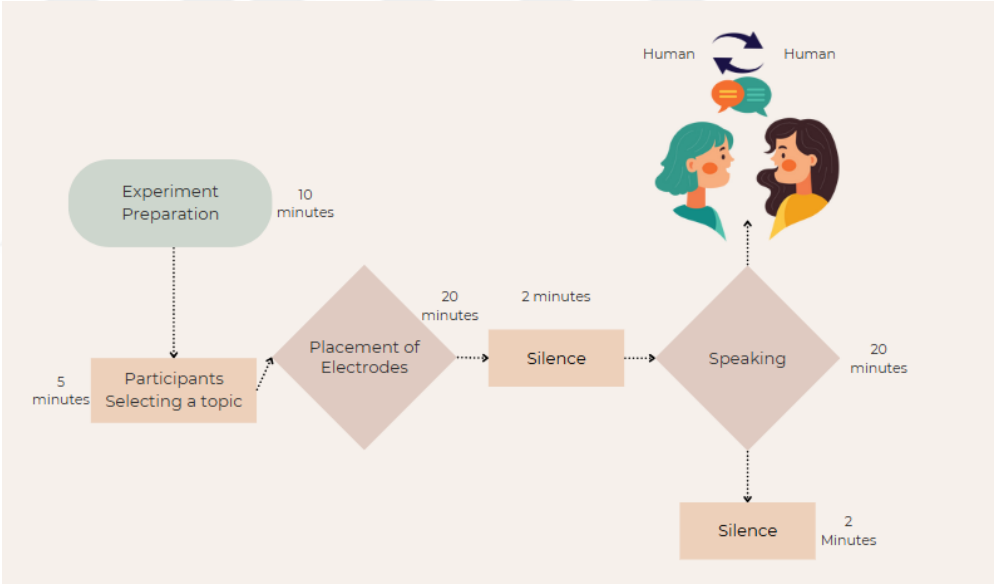


The HHI group was also instructed that they would directly engage with the researcher and reminded to maintain stillness to eliminate any muscle artifacts that could negatively impact the results. The process of data collection for the HHI group is illustrated in Figure 12. Furthermore, the participants were given explicit instructions for the recording session, which involved 2 minutes of silence, followed by 20 minutes of speaking, and closing with an additional 2 minutes of silence, resulting in a total duration of 24 minutes (Figure 13).

Figure 12. The HHI Group Data Collection



Figure 13. The HHI Group Data Collection Process

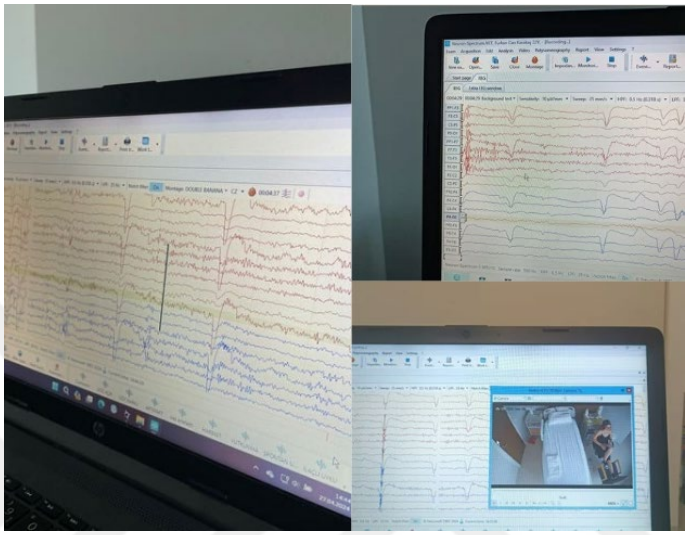


3.7.5. EEG Recording Procedures

The first part of the recording process involved 2 minutes of silence, allowing participants to acclimate to the electrodes on their heads and become more comfortable. During this time, the researcher also checked for any issues with electrode placement and ensured the normality of the brainwave readings (Figure 14). Following this acclimation period, participants were instructed to begin speaking. This speaking session lasted for 20 minutes. Throughout this period, brainwave activity was continuously monitored, and participants were observed via camera to ensure minimal movement, which could affect the accuracy of the EEG data. When the speaking

session ended, participants were instructed to stop speaking and remain still for an additional 2 minutes. This post-session stillness period was crucial for obtaining baseline brainwave data for comparison with the active speaking period. To provide an artifact-free period, the EEG recording included 24 minutes (Sinha et al., 2016).

Figure 14. EEG Recordings



3.7.6. Qualitative Data Collection

The qualitative data were obtained through semi-structured interviews, which are a commonly employed method for gathering quantitative data (DiCicco-Bloom & Crabtree, 2006). The purpose of these interviews was to achieve an in-depth understanding of the phenomenon being studied. The primary objectives of the semi-structured interviews are to explore the participants' experiences and gather their perspectives regarding the study. Following the EEG sessions, the participants and the researcher collaborated to establish an appropriate timetable for the interview sessions. Individual face-to-face interviews with each participant were performed, which ensures a comfortable and confidential environment to encourage open and honest communication. The interviews were recorded with the participants' consent and later transcribed for analysis. These interviews aimed to capture nuanced details about the participants' experiences and the impact of human and chatbot interactions while performing English speaking tasks.

While the questions followed the same overall structure, they were tailored to each group's specific interaction experience. The questions listed below were tailored for the HCI group:

1. How did you find the experience of practicing English speaking tasks with ChatGPT?
2. Can you describe specific moments during the study where you found the chatbot to be particularly helpful or challenging for practicing speaking?
3. Based on your experiences, what are the strengths and weaknesses of using a chatbot for practicing English speaking tasks?
4. How do you think ChatGPT could be improved to better assist in practicing speaking tasks?
5. Did you encounter any technical issues or difficulties while using the chatbot for speaking tasks? How did these affect your experience?

The questions listed below were tailored for the HHI group:

1. How did you find the experience of practicing English speaking tasks with a human instructor?
2. Can you describe specific moments during the study where you found interacting with the human instructor to be particularly helpful or challenging?
3. What are the strengths and weaknesses of using human interaction for practicing English speaking tasks, based on your experiences?
4. Did you encounter any difficulties or challenges during your speaking sessions with the human instructor?
5. What characteristics of the human instructor did you find most effective for learning to speak English?

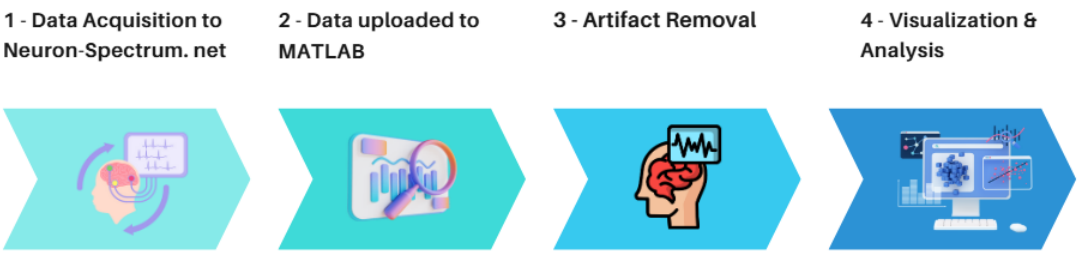
3.8. Data Analysis

The data analysis process involved a combination of quantitative EEG data and qualitative data. Before the main data collection, demographic information about participants, including age and prior experience with ChatGPT, was gathered through Google Forms. The data were organized in Excel using unique participant codes (e.g., P1, P2) to ensure anonymity and were subjected to statistical analyses to calculate descriptive statistics as part of the preliminary analysis.

For the quantitative component, EEG data were first obtained using the Neuron-Spectrum.NET software connected to the EEG device and then transferred onto a CD for storage and further analysis. MATLAB and SPSS were used to conduct an in-depth statistical analysis of the EEG data. In parallel, qualitative data were analyzed using MaxQDA to identify thematic patterns.

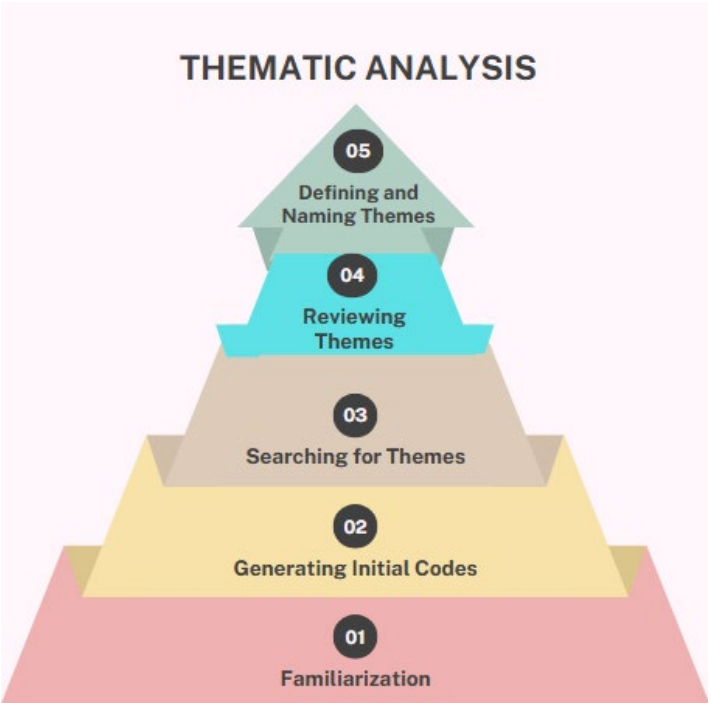
In order to answer RQ1 and RQ2, the EEG data transferred to MATLAB were imported using the EEGLAB toolbox, with the dataset loded in set format via the command "EEG = pop_loadset ('filename', 'your_file.set');" After successfully uploading the data set, several codes were written to perform the necessary analyses. One of the key preprocessing steps involved removing artifacts caused by eye blinks, muscle movements, or external noises. For this purpose, Independent Component Analysis (ICA) was employed through the EEGLAB command "EEG = pop_runica (EEG, 'extended', 1)". As a result, a cleaner database was obtained, which enhanced the reliability and accuracy of the findings. After artifact removal, visual graph analyses were utilized to interpret the EEG data since the sample size was large and the dataset was complex. These visuals included frequency-specific maps for alpha (8–12 Hz) and theta (4–8 Hz) rhythms. They were helpful in comparing the HCI and HHI groups effectively by offering a comprehensive view of the brain activities. To complement the analysis, statistical tests on the EEG data were utilized using SPSS software. Descriptive statistics, including means and standard deviations, were calculated within each group. An independent samples t-test was conducted to compare the HCI and HHI groups to assess significant differences. The statistical analyses produced a p-value that determined the statistical significance of the observed differences. Therefore, the combination of Neuron-Spectrum.NET software, MATLAB, and SPSS offered a comprehensive framework for the data analysis of EEG recordings. They offered a solid foundation for understanding the neurological processes underlying the study (See Figure 15).

Figure 15. EEG Data Analysis Process



On the other hand, to answer RQ3, qualitative data obtained from semi-structured interviews were analysed using thematic analysis in MAXQDA 24. Thematic analysis, which is a foundational method in qualitative analysis (Braun & Clarke, 2006), involves systematically coding the data, identifying recurring themes, and interpreting participants' responses to provide deeper insights into their experiences and perceptions. Braun and Clarke (2006) described thematic analysis as "a method for identifying, analysing and reporting patterns (themes) within data. It minimally organizes and describes your data set in (rich) detail." (p.79) It is a systematic method which includes several steps such as familiarization with data, identifying general codes, colleting codes into potential themes, reviewing and naming the final themes (Terry et al., 2017). (See Figure 16.)

Figure 16. Thematic Analysis



Therefore, as a first step, the data were familiarized through repeated reading. The coding process was handled meticulously since it is a critical link between data collection and the explanation of meaning (Charmaz, 2001). Themes, the analytical outcomes of coding (Saldaña, 2021), began to emerge though extensive revisions. After revision, themes were named accordingly to represent the data. Finally, the top-code, sub-code statistics and word clouds was generated in MAXQDA to visualize and summarize the data.

4. RESULTS

The results section aims to provide statistical findings corresponding to each research question and consists of two subsections: quantitative and qualitative results. Under the first subsection, findings of EEG recordings are presented, while thematic analysis results are reported in the second part of this section.

4.1. Quantitative Results

4.1.1. Research Question 1: Does alpha activity, as measured by an EEG device, differ between human-human interaction (HHI) and human-chatbot interaction during real-time English-speaking tasks?

Statistical differences ($p<0.005$) in alpha activity were identified across different regions in two groups (see Table 5 below). Table 5 presents mean values and standard deviations (±) for the alpha rhythm at eight electrode sites (Fz, Cz, FP1, C3, F3, F7, T3, T5) for both the HCI and HHI groups.

Table 5. Mean and Standard Deviation of Alpha Rhythm (μV) Across Brain Regions

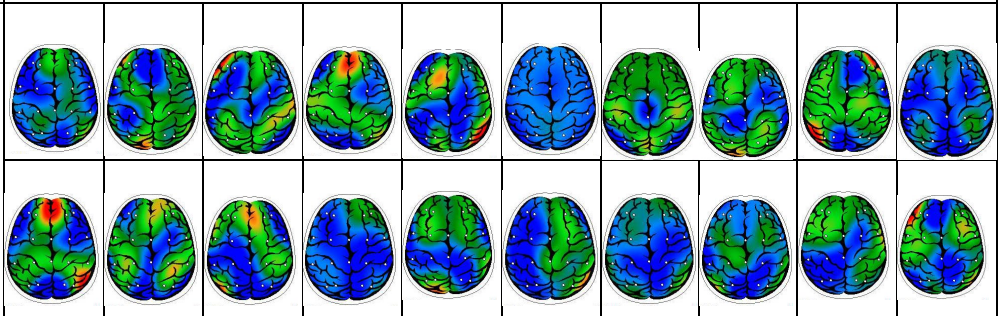
Alpha-rhythm, μV / Groups	Fz	Cz	FP1	C3	F3	F7	T3	T5
The HCI Group	674.74 ±19.08	466.50 ±15.74	798.33 ±12.76	**658.98 ±21.98**	784.53 ±17.01	759.89 ±11.16	**648.15 ±26.32**	**692.45 ±18.59**
The HHI Group	718.65 ±38.52	**801.64 ±25.98**	**1115.46 ±35.60**	483.70 ±31.81	771.58 ±24.79	**1055.55 ±42.01**	279.85 ±38.35	446.16 ±41.63

*p<0.005

The HHI group displayed significantly higher levels of alpha activity in Cz, FP1, and F7 sites in the left region of the scalp, with values of 801.64 μV, 1115.46 μV, and 1055.55 μV compared to the HCI group, interacting with a chatbot, where the alpha activity at these regions was 466.50 μV, 798.33 μV, and 759.89 μV, respectively. Conversely, the HCI group, engaging in chatbot interaction, exhibited significantly higher alpha activity in T3 and T5 electrodes on the temporal lobe in the left region of the scalp, where corresponding values were 648,15 μV and 692,45 μV than the HHI group, whose values were 279,85 μV and 446,16 μV, respectively. Besides, at the C3 site, the HCI group demonstrated elevated alpha activity with 658,98 μV compared to the HHI group, where the value was 483,70 μV.

Additionally, alpha rhythm map was visualized to emphasize the variations in the HHI and HCI groups (as seen in Table 6). The color-coded map intended to highlight differences in alpha brain wave activities. The warmer colors refer to higher alpha activity while cooler colors inditicate lower alpha activity. As consistent with the the Table 6, the HHI group exhibited higher alpha activity than the HCI group. Figure 17 demonstrates the means of both groups.

Table 6.Alpha Rhythm Map (8.0-14.0 Hz)

Groups	**Alpha Rhythm Map**
The HCI	

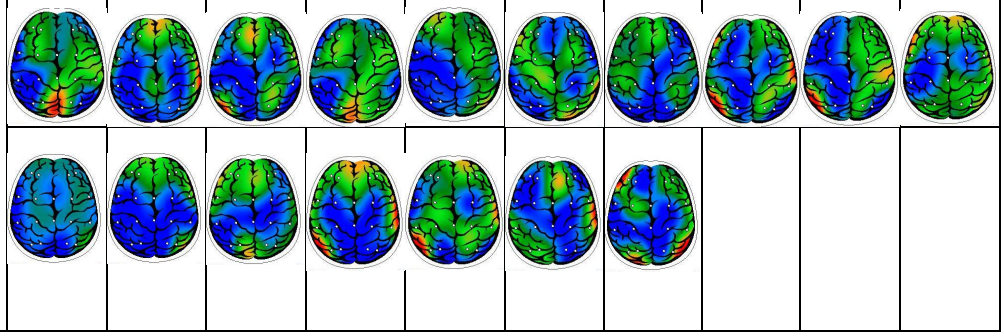
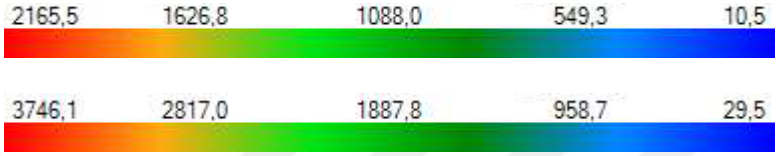
The HHI	

Figure 17. Mean of the HCI and HHI Groups



4.1.2. Research Question 2: Does theta activity, as measured by an EEG device, differ between human-human interaction (HHI) and human-chatbot interaction during real-time English-speaking tasks?

The differences between the HHI group and the HCI group, in terms of theta activity, were illustrated in Table 7, and statistical differences ($p<0.005$) in theta activity were identified across various regions in the two groups. The HCI group demonstrated notably higher theta activity in C3, F3, T3, and T5 regions compared to the HHI group. In C3 and F3 cites, the frontal regions, the HCI group exhibited elevated theta activity, with the values of 609,765 µV and 804,62 µV, respectively. Additionally, in the temporal lobes, T3 and T5, the HCI group maintained its dominance compared to the HHI group, with the values of 570,71 µV and 726,125 µV, respectively. Therefore, the theta activity presence was stronger in the frontal and temporal lobes in the HCI group.

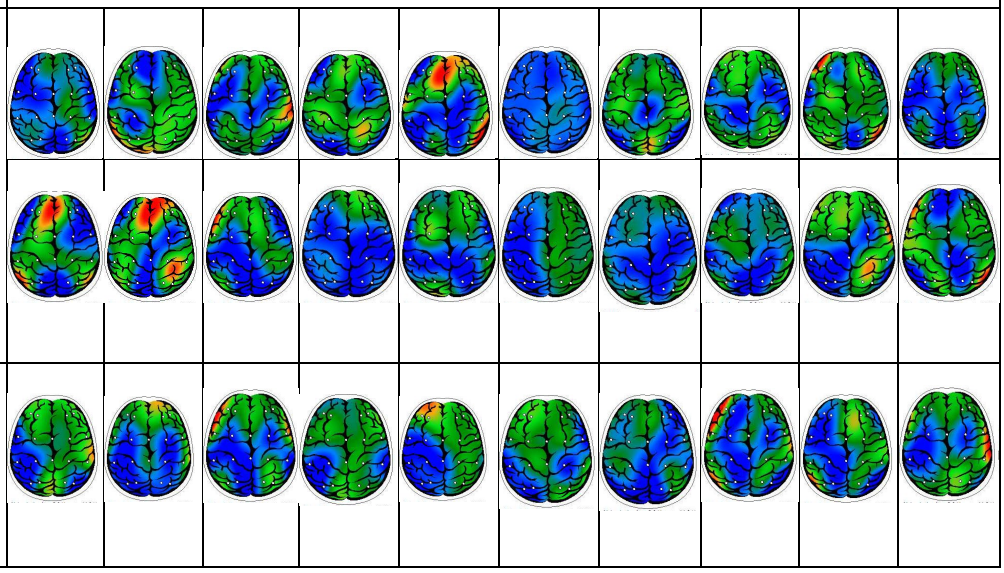
Furthermore, theta rhythm maps were presented to accentuate the differences between the HHI and HCI groups (as illustrated in Table 8). The color-coded map was intended to emphasize the variations in theta brain wave activities. Higher theta activity is indicated by warmer colors, while lower theta activity is indicated by colder colors. The HCI group exhibited a higher theta activity than the HHI group, as indicated by Table 8. Besides, Figure 18 demonstrates the means of both groups.

Table 7.Mean and Standard Deviation of Theta Rhythm Activity (µV) Across Brain Regions

Theta Rhythm (µV) / Groups	Fz	Cz	FP1	C3	F3	F7	T3	T5
The HCI Group	797.185 ±23.09	408.73 ±21.37	881.435 ±28.36	**609.765 ±27.13**	**804.62 ±18.71**	619.125 ±16.93	**570.71 ±20.12**	**726.125 ±29.13**
The HHI Group	852.240 ±41.02	407.99 ±15.68	981.817 ±31.67	303.335 ±38.11	536.21 ±22.63	601.70 ±19.01	384.017 ±11.28	502.682 ±26.53

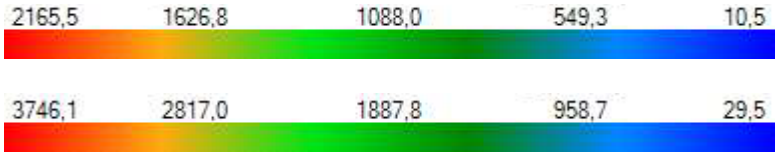
***p<0.005**

Table. 8. Theta Rhythm Map (4.0-8.0 Hz)

Groups	Theta Rhythm Map
The HCI Group	
The HHI	

Group										

Figure 18. Means of the HCI and HHI Groups



4.2. Qualitative Results

4.2.1. Research Question 3: What are EFL students' perceptions of human-human (HHI) and human-computer interaction (HCI) using AI-mediated tools, like chatbots, in English speaking tasks?

Using thematic analysis, several themes for each interaction type emerged. A codebook was created to systematically categorize responses, with initial codes generated based on a preliminary assessment of the data, as part of this process. Subsequently, these codes were further refined through multiple rounds of coding and analysis, which enabled the emergence of themes for each interaction type. This part was divided into two subtitles: (1) the HCI group, which engaged with a chatbot in EFL spoken tasks qualitative analysis, and (2) the HHI group, which interacted with a human in EFL spoken tasks qualitative analysis.

4.2.2. The HCI group qualitative analysis

Thematic analysis revealed two primary themes: Perceived Strengths of ChatGPT in Language Learning and Perceived Challenges of ChatGPT in Language Learning (refer to Table 9), each encompassing several subthemes (refer to Tables 10 and 11).

Table 9. Top-Level Code Statistics of the HCI group

Top-Level Code Statistics	Segments	Percentage
Perceived Strengths	115	60.21
Perceived Challenges	63	32.98
TOTAL	191	100.00

With 115 coded segments (60.21% of all segments), the perceived strengths of ChatGPT, an AI-mediated tool, were frequently pronounced by the participants. The subcodes were created under this theme, which were demonstrated in both Figure 19 and Table 10. Among subthemes, the most mentioned strengths of ChatGPT are the comfort that it provides to the learners (14.78 %) and its practicality in improving English speaking skills (13.91%).

Participants described feeling more at ease with the AI, as one noted:

"*Sometimes, I feel stuck when I speak English with a human, which often makes me worried about mistakes. However, I felt safe and comfortable practicing with ChatGPT." (P1)*

"*I was actually more at ease, as I would become more anxious if I were conversing with a human." (P2)*

Besides, participants expressed ChatGPT's practicality in improving language skills:

"*Additionally, by actively listening to the chatbot's responses, you can enhance your pronunciation, listening comprehension, vocabulary, and grammar skills, as it offers authentic language usage." (P3)*

"I think that language teachers, practitioners, and the students can easily integrate it into their English-speaking teaching and learning." (P4)

"One can find many ways to facilitate the English-speaking process with it." (P5)

The tool was also valued for its persistent conversational support (9.57%) and engaging experience (7.83%):

"I believe that it made the conversation go in a perfect way. It was very smooth. It was, I believe, way more successful than a human." (P6)

"I believe that utilizing conversation GPT can be beneficial in generating new speaking prompts and questions. I mean, the answers will never be worn out as there is always something novel to discover." (P7)

Other positive aspects of ChatGPT included the non-judgmental environment that it offers, which was identified as important for mitigating anxiety in language practice by the participants (7.83%). The participants noted that:

"Individuals often experience a degree of shyness when conversing in a foreign language. Therefore, they are inclined to evade engaging in real-life interactions in English. Engaging with a human-like entity such as GPT beforehand can serve as beneficial preparation, allowing them to practice before conversing with native speakers or fluent individuals in real-life settings. This approach is particularly advantageous for those who suffer from social anxieties." (P1)

"If one identifies oneself as an introverted individual, interacting with a chatbot can definitely be comforting. Unlike human interactions, there is no concern about feeling uncomfortable or facing judgment, regardless of what you say." (P8)

Some of the participants further expressed that they could speak more freely since it is not a human.

Additionally, the 24/7 availability (4.35%) of ChatGPT, the time-saving (3.48%) feature that it has, and the customized learning environment (2.61%) that it provides were appreciated by the participants. The participants noted that:

"I believe that the primary advantage of utilizing a chatbot for practicing English speaking tasks lies in its continuous availability. You have the flexibility to practice anytime and anywhere, for as long as you desire. Furthermore, it offers the invaluable benefit of receiving feedback comparable to that of having a private tutor." (P9)

"At present, this stands as one of the most effective tools for learning. Its round-the-clock availability offers learners an unparalleled resource, a stark contrast to the limitations inherent in human interactions." (P10)

"I prefer using ChatGPT due to its unparalleled convenience. Rather than typing lengthy texts, I frequently communicate with ChatGPT verbally, which significantly saves time and effort. This functionality is especially advantageous when I'm too lazy to type or when multitasking and needing to keep my hands free." (P11)

"*Initiating conversations with prompts regarding the learners' age, proficiency level, and even their interests and hobbies allows ChatGPT to tailor its responses accordingly. This personalized approach can significantly enhance the learning experience." (P12)*

Figure 19. Perceived Strengths of ChatGPT in English Speaking Context

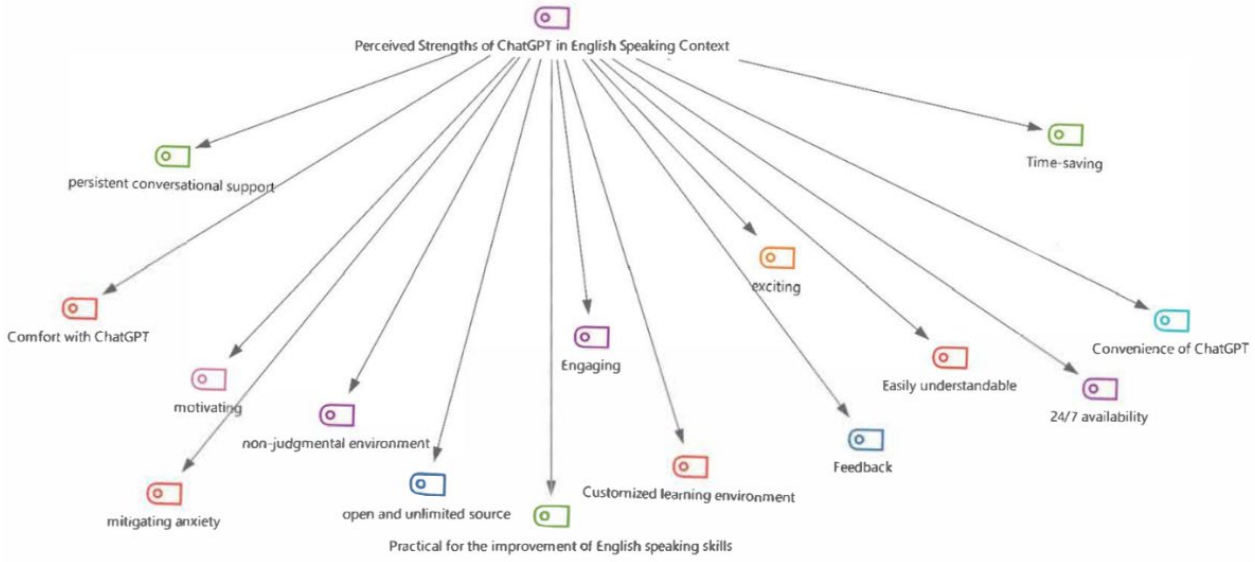


Table 10. Subcode Statistics- Perceived Strengths of ChatGPT in English Speaking Context

Perceived Strengths	Segments	Percentage
Comfort with ChatGPT	17	14.78
Practical for the improvement of English-speaking skills	16	13.91
Persistent conversational support	11	9.57
Engaging	9	7.83
Mitigating anxiety	9	7.83
Non-judgmental environment	9	7.83
Open and unlimited source	6	5.22
Convenience of ChatGPT	6	5.22
Easily understandable	5	4.35
24/7 availability	5	4.35
Time-saving	4	3.48
Customized learning environment	3	2.61
Exciting	3	2.61
Motivating	3	2.61
Feedback	2	1.74
TOTAL	115	100.00

Participants, in addition to these strengths of ChatGPT, identified its challenges as reflected in 63 coded segments (32.98% of all segments), illustrated in Table 11 and Figure 20 7 subcodes were established under this theme based on recurring terms. Among these, at 39.68%, the most frequent issue addressed was the inability of ChatGPT to mimic human emotions. They expressed that those interactions with GPT lacked physical attachment and non-verbal communication that are present in human interaction, which they found "unnatural" at 3.11%. They explained that as:

"I believe, because you need someone to accept you, or at least refuse you with their gestures, too. You need to be confirmed sometimes. So, no matter what the intonation is, you always know that it's a robot talking in front of you. To some extent, it feels real, but it's not so real and you're aware of this." (P13)

"You never experience the emotions immediately because you can't look someone in the eye, face to face. Instead, you find yourself waiting for a message from a chat, which makes it somewhat challenging." (P13)

"Its unnatural characteristics created the impression of conversing with a robot rather than engaging in a genuine conversation, which can be quite frustrating." (P14)

They also stated that *"it won't be the equivalent of a five-minute conversation with a real human." (P14)*

"*If I were to converse with a human, there would be an array of emotions, facial expressions, and body language. These non-verbal cues can influence my responses since there's a living person in front of me. Therefore, it wasn't easier for me to communicate with the machine, knowing its responses and questions were more mechanical." (P15)*

Technical issues were also prominent, at 28.57%, among the challenges. These encompassed issues such as response delays or disruptions, which were found annoying by the participants. They noted that as:

"It did occasionally interrupt my speech, which became annoying after it happened three times. I believe this is a technical issue that ChatGPT needs to address, as it asks for feedback on whether the chatbot interrupted your speech after you finish talking." (P16)

"Since it always interrupted me, gave unrelated answers to me, ChatGPT made me feel overwhelmed throughout the process." (P17)

Therefore, in addition to technical issues that it has, speech interruption (11.11%) and unrelated responses (7.94%) were noted as problematic. Other challenges appeared as the unpredictability of ChatGPT's responses (4.76%), and its usage ''perfect'' or formal English (4,76%).

"I was feeling less comfortable because I was worried about the answers that it would give to me since I don't have the opportunity to look someone in the eyes" (P16)

"It speaks too fast and uses "perfect" English, which required me to draw attention a lot." (P9)

Figure 20. Challenges of Using ChatGPT in English Speaking Context

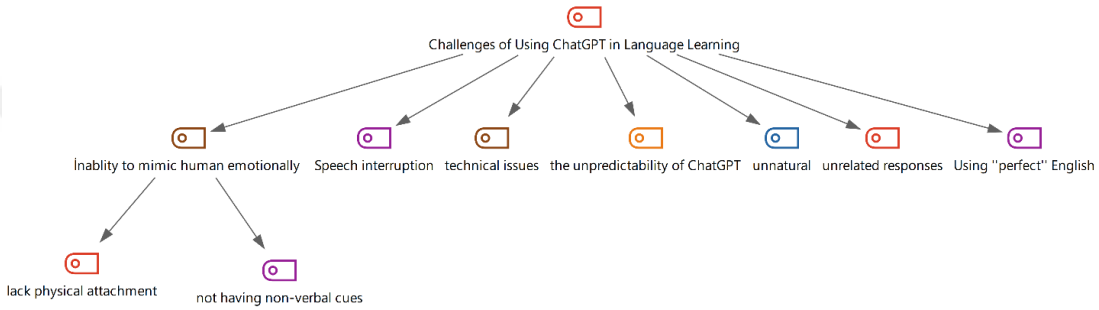


Table 11. Subcode Statistics- Challenges of Using ChatGPT in English Speaking Context

Challenges of using ChatGPT	Segments	Percentage
Inability to Mimic Human Emotion	25	39.68
Technical Issues	18	28.57
Speech Interruption	7	11.11
Unrelated Responses	5	7.94
The Unpredictability of ChatGPT	3	4.76
Using "Perfect" English	3	4.76
Unnatural	2	3.17
TOTAL	63	100.00

4.2.3. The HHI Group Qualitative Analysis

Thematic analysis revealed two primary themes: Perceived Strengths of Human-Human Interaction in EFL Speaking Tasks and Perceived Challenges of Human-Human Interaction in EFL Speaking Tasks (refer to Table 12). Each encompasses several subthemes (refer to Tables 13 and 14).

Table 12. Top-Level Code Statistics

Top-Level Code Statistics	Segments	Percentage
Perceived Strengths	128	79.50
Perceived Challenges	4	2.48
TOTAL	161	100.00

The most coded with 128 segments at 79.50% subtheme was Perceived Strengths of Human-Human Interaction in EFL Speaking Tasks. 4 subcodes were established based on recurring terms (See Table 13 and Figure 21). The most frequently expressed characteristics of HHI were the role of non-verbal cues in enhancing understanding (45.38%). The participants appreciated the body language of HHI, which enables them to comprehend better in conversation. They stated that as:

"*When discussing with the interlocutor, the responses, along with her body language and tone of voice, significantly helped me recognize that I was conversing with someone who understood and validated my feelings." (P36)*

"I was able to read her body language and facial expressions, and even if I couldn't fully articulate my thoughts in complete sentences, I knew she could understand me." (P19)

"Eye contact, body language eased the flow of the conversation. Having a face to look at and speak as humans, we are like social creatures that helped me more than talking to a screen." (P18)

"Gestures, eye contact made me feel more comfortable as she gave cues on how she understood me with her body language by nodding her head." (P21)

The participants, in addition to non-verbal communication, expressed how they felt comfortable throughout the conversation. The participants highlighted that:

"*I have always had a positive outlook on human interaction in the context of language learning. I found it comfortable and easy to converse with a human." (P22)*

"Conversing with a computer or artificial intelligence lacks the natural elements of human interaction. It cannot perform bodily movements or provide reassurance with gestures such as a nod or a blink. Therefore, seeing a face in front of me made me feel comfortable." (P24)

Building emotional connections in HHI was also prominent in the list of the strengths of human-human interaction at 16.15%. They expressed their feelings:

"*I could easily attach emotionally in the process of having a conversation with a human, I do not believe it will be the same in the engagement with an AI tool." (P31)*

"I can express my emotions because I'm interacting with a human who can understand my non-verbal cues, such as head movements. Seeking approval through gestures like nodding is intrinsic to our communication. It's about emotions; I can effortlessly convey my feelings to you." (P25)

The participants also appreciated the active engagement characteristics of human interaction (11.54%). One highlighted that:

"When interacting with a person, they can respond to my emotions, provide immediate feedback, and ask follow-up questions based on my input. This dynamic exchange makes the conversation feel lively and helps me stay focused." (P26)

"Speaking English with a human is so natural, and I can perceive a human as an authority, which keeps me engaged along with the conversation." (P28)

Figure 21. Perceived Strengths of Human-Human Interaction in EFL Speaking Tasks

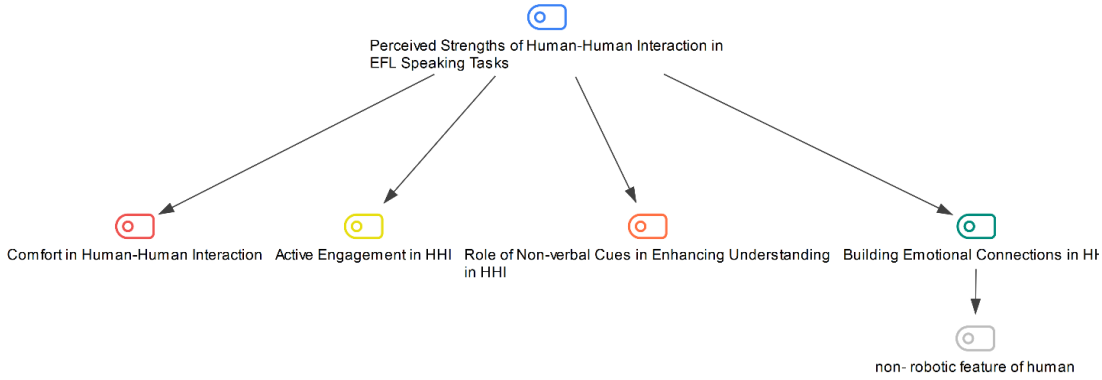


Table 13. Subcode Statistics- Perceived Strengths of Human-Human Interaction in EFL Speaking Tasks

Perceived Strengths	Segments	Percentage
Role of Non-verbal Cues in Enhancing Understanding	59	45.38
Comfort in Human-Human Interaction	35	26.92
Building Emotional Connections	21	16.15
Active Engagement	15	11.54
TOTAL	130	100.00

Despite benefits of non-verbal language, active engagement and emotional connection in human-human interaction, some participants also reported challenges related to speaking English while interacting with a human. All identified challenges were related with anxiety and a sense of being judged in HHI (100%) as shown in Figure 22 and Table 14.

The participants expressed their sense of discomfort as:

"*Having a conversation with a human interlocutor in terms of affective filter, considering the anxiety, might be difficult, because when choosing the words, you have to be pickier." (P33)*

"Since it is not the same experience as engaging with a computer, interacting with a person can lead to thoughts about how one is perceived, causing anxiety and a feeling of being judged." (P30)

"Just as they can observe me, I can observe them as well, and they can read my body language. When compared to interacting with a robot, the knowledge that a robot lacks the capacity to judge me makes the process smoother with a greater sense of comfort." (P35)

"I was a little nervous about whether she judged me or about my pronunciation, my grammar rules." (P37)

Figure 22. Perceived Challenges in Human-Human Interaction in EFL Speaking Tasks

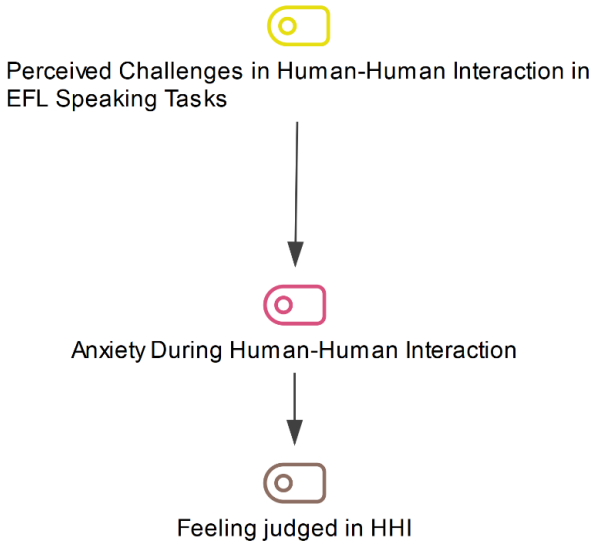


Table 14. Subcode Statistics- Perceived Challenges of Human-Human Interaction in EFL Speaking Tasks

Perceived Challenges	Segments	Percentage
Anxiety During Interaction	9	100.00
TOTAL	9	100.00

5. DISCUSSION

Research Question 1:

The first research question investigated whether alpha activity, as measured by EEG, differs between HHI and HCI during real-time English-speaking tasks. The results revealed statistically significant differences ($p < 0.005$) in alpha activity across various regions of the scalp between the HHI and HCI groups. Specifically, the HHI group exhibited higher alpha activity in the frontal regions, including Cz, FP1, and F7, while the HCI group displayed heightened alpha activity in the temporal lobe regions, particularly at T3 and T5. Notably, FP1 is known to be particularly sensitive to affective and emotional regulation, suggesting that the presence of a real human interlocutor may have elicited a more emotionally attuned and comfortable interaction state. Meanwhile, the heightened temporal alpha activity (T3 and T5) in the HCI group points to increased reliance on auditory processing and predictive mechanisms, likely due to the absence of visual and gestural cues in chatbot interaction. These variations imply that while HHI promotes deeper cognitive and emotional alignment, HCI requires listeners to compensate for missing multimodal input by allocating more neural resources to auditory interpretation. These variations can be interpreted in light of differences in cognitive load, emotional involvement, and communicative authenticity between human-human and human-chatbot interactions. Additionally, variations in alpha distribution may reflect distinct memory and attentional processes activated by each interaction type.

Prior studies showed that frontal alpha activity is associated with cognitive efficiency and memory maintenance in contrast to cognitive effort (Klimesch et al., 2007; Rugg et al., 1996). Additionally, the studies suggested that a heightened alpha activity in the frontal lobe is observed to minimize interference and maintain stored information during memory retention (Amin & Malik, 2013; Chen et al., 2023; Sauseng et al., 2005). For example, Klimesch et al. (2007) highlighted the role of alpha oscillations in long-term and working memory tasks. They found that increased alpha activity during information retrieval acts as an inhibitory mechanism that helps suppress

irrelevant information. In a similar vein, Jensen et al. (2002) investigated the role of alpha oscillations in working memory by recording EEG activity during the retention interval of a modified Sternberg task. They revealed that alpha power in the 9–12 Hz range systematically increased with memory load, indicating that alpha oscillations play an active role in memory maintenance. Therefore, and in light of previous literature, observing higher frontal alpha power in the HHI group may demonstrate more effective memory retrieval and attentional regulation during interaction with a human partner compared to HCI. In addition, Kawasaki et al. (2013) investigated inter-brain synchronization in HHI versus human-machine interaction (HMI) and found that alpha amplitudes were significantly higher during HHI. Similarly, Dumas et al. (2010) explored inter-brain synchronization during social interactions that require working memory. Their findings revealed increased alpha activity when participants were synchronized in their movements, highlighting the cognitive alignment that occurs during naturalistic human interaction. These findings imply that participants in the HHI group (HHI) may have exhibited more efficient attentional regulation and memory retrieval compared to those in the chatbot interaction group. This may be attributed to the multimodal nature of HHI, where verbal, visual, and gestural cues work together to reduce cognitive strain (Clark, 1998; Drijvers & Holler, 2023). In contrast, the HCI group, relying solely on auditory input, may have experienced increased cognitive load due to the absence of such contextual support. Building on this, engaging in collaborative conversations or tasks within HHI contexts has been shown to stimulate cognitive processes, including memory encoding and retrieval. Such active participation can enhance brain function and improve memory performance (Ackerman, 2011; Marian et al., 2021). Moreover, several studies have demonstrated that the physical properties of the human body, particularly gestures, play a significant role in cognition. Memory is often enhanced when individuals interact with a speaker who uses gestures (Clark, 1998; Thompson, 1995), which may explain the observed differences in alpha band activity in the frontal lobes across the two interaction types. Higher alpha power in the HHI group may reflect a more optimized and effortless cognitive processing state, whereas the HCI group, lacking multimodal cues, may have required greater cognitive effort to maintain engagement. However, contrasting findings were reported by Oliver et al. (2024), who observed lower alpha power in the parietal and occipital regions during a multimodal robotic task. While their results still support the idea that multimodal interaction increases

engagement, the discrepancy may stem from the nature of the tasks: their study focused on task-driven robotic engagement, whereas the current study investigated naturalistic social interaction.

The heightened alpha activation in temporal lobe regions (T3 and T5) is commonly associated with increased attention in auditory processing (Russell-Chapin et al., 2020). The participants engaged with ChatGPT interaction demonstrated higher alpha activation in temporal lobe regions, which refers to increased auditory processing compared to the HHI group. This observation emphasizes the role of temporal lobe regions in processing auditory and contextual information in environments where multimodal cues are limited, such as ChatGPT interactions. Multimodal information is the main source of communication, and human-human interaction is inherently multimodal, encompassing simultaneous auditory and visual signals, such as speech, hand gestures, facial expressions, and head movements (Benetti et al., 2023; Drijvers & Holler, 2023). However, in ChatGPT interaction, individuals mostly rely on incomplete signals due to the absence of facial expressions, and in this situation, the brain tends to fill in these gaps within a process described by the Bayesian brain hypothesis (Maunsell & Van Essen, 1983). This hypothesis posits that in interactions with limited multimodality, the brain functions as a predictive machine. These predictions are iteratively resolved through top-down and bottom-up interactions (Itti & Baldi, 2009). In line with this compensatory mechanism, previous studies have shown that interactions with ChatGPT can enhance listening skills by fostering attentive engagement and repeated auditory practice, requiring users to rely heavily on active listening (Fidan & Gencel, 2022; Hsu et al., 2021; Tai & Chen, 2022). Therefore, in the context of ChatGPT interaction, the lack of physical and non-verbal cues likely triggered bottom-up compensatory mechanisms in the temporal lobe, which refers to more attentive listening. This explains the finding of the heightened activity in the temporal lobe in chatbot interaction, as human-human interaction comprises multimodal signals that work in harmony to provide redundant information for the individuals. Studies demonstrated that participants respond faster when combined with multimodal signals (Nagels et al., 2015). Similarly, questions accompanied by gestures elicit faster responses than those without such gestural components (Ter Bekke et al., 2020).

Among the findings of the study, these findings offer significant insight into the neural mechanisms underlying HHI and HCI, AI-mediated chatbots. Observed alpha activity

across frontal and temporal regions consists of distinct patterns and highlights the different cognitive demands imposed by the two interaction types. In HHI, where multimodal cues and social engagement are redundant, memory retrieval and working memory processes are enhanced, reflected in heightened frontal alpha activity. However, in HCI, especially chatbots, there is a greater reliance on auditory processing as evidenced by increased temporal alpha activation.

Research Question 2:

The second research question investigated whether theta activity, as measured by an EEG device, differs in HHI and HCI during real-time English-speaking tasks. The results indicated the HCI group exhibited higher theta activity in C3, F3, T3, and T5 regions compared to the HHI group. HCI observed a heightened theta activity in the frontal and temporal lobes. The elevated theta activity observed in the frontal (F3, C3) and temporal (T3, T5) regions of the HCI group suggests engagement in cognitive processes such as working memory maintenance, predictive language processing, and possibly emotional self-regulation. The frontal regions, especially F3, are often associated with executive control and attention regulation, implying that participants interacting with the chatbot were actively managing verbal information and anticipating turns in the absence of non-verbal cues. Meanwhile, increased temporal theta activity, notably at T3 and T5, likely reflects a heightened demand for auditory processing and verbal memory retrieval. This pattern may also indicate a reduction in social pressure, as theta oscillations have been linked to relaxed, meditative, and less anxious mental states. Thus, the increased theta activity in HCI interaction may reflect both greater cognitive effort and a calmer, less socially demanding environment compared to HHI.

Prior studies suggested that theta oscillations are closely related to cognitive control (Senoussi et al., 2022), memory retrieval (Chikhi et al., 2024), and cognitive effort (Eschmann, 2022). They are also intricately associated with relaxed attentional states and emotional regulation (Jacobs & Lubar, 1989; Tang et al., 2019). The observed increase in theta activity in the HCI group may therefore reflect a shift in cognitive and emotional processing. The absence of multimodal cues likely enhances reliance on memory and predictive mechanisms, resulting in increased cognitive effort, while simultaneously alleviating some of the social demands typically present in human-human interaction.

A growing body of literature highlights the involvement of theta oscillations in working memory and episodic memory processes. This activity has been widely associated with maintenance, retrieval, and memory encoding, especially in tasks where there is a need for holding and manipulation of the information over short periods (Sauseng et al., 2010). Studies showed that frontal theta power increases as working memory load intensifies (Cavanagh & Frank, 2014), while temporal theta activity plays a critical role in verbal memory recall and language comprehension (Bastiaansen et al., 2005). The observed elevation in frontal and temporal theta power in the HCI group suggests that chatbot interaction demanded greater reliance on memory retrieval and predictive processing. This may be due to the absence of multimodal cues, which increased the need to retain and process speech-based information internally. These findings are consistent with evidence showing that theta synchrony between the prefrontal cortex and hippocampus supports memory-based language processing, enabling individuals to maintain conversational flow when external cues are limited (Benchenane et al., 2011; Klimesch et al., 2000). Additionally, research demonstrated that there is an increase in theta activity when there is a demand for linguistic tasks in which the individuals should predict the upcoming speech (Meyer et al., 2015). The results indicating higher temporal theta activity in the HCI group support the idea that participants engaged in predictive processing, where there is a requirement for anticipating conversational turns due to the lack of non-verbal cues present in HHI. This supports the broader view that theta oscillations mark effortful cognitive engagement, particularly in contexts where speech processing becomes more demanding (Chikhi et al., 2024; Eschmann, 2022). Therefore, the higher activity in temporal theta in the HCI group reflects the increased reliance on auditory and predictive language mechanisms.

Although theta oscillations are closely linked to memory retrieval and cognitive control, they are also intricately related to relaxation, meditative states, and reduced anxiety (Baijal & Srinivasan, 2010; Jacobs & Lubar, 1989; Tang et al., 2019). Studies on mindfulness and meditative states demonstrated the increased theta activity in low-stress environments where cognitive engagement is present but free from external social pressures (Lagopoulos et al., 2009). The GPT interaction group exhibiting higher theta activity may have induced a state of relaxed engagement, avoiding the social pressures inherent in HHI. Previous research revealed that when individuals regulated stress, an increase in theta activity was observed (Ertl et al., 2013). This

aligns with findings that theta oscillations play a role in emotional control and reduced anxiety, particularly in environments where individuals feel less judged or scrutinized (Tang et al., 2019). Besides, a study conducted by Hsu (2022) to investigate portable EEG responses to chatbot interactions revealed that theta oscillations were more dominant in AI-based communication, a result that corresponds with the findings of the present research. Thus, higher theta activity in the HCI group may reflect not only the increased cognitive engagement but also a stress-reducing effect. These findings align with prior research suggesting that chatbot-mediated English-speaking tasks reduce learner anxiety (Fryer & Carpenter, 2006; Hapsari & Wu, 2022; Koç & Savaş, 2024).

The findings of this study indicated that theta power was significantly higher in both the frontal (F3, C3) and temporal (T3, T5) regions in the HCI group compared to the HHI group. In the HCI group, individuals experienced increased reliance on working memory and predictive language processing compared to the HHI group, which may have resulted from the absence of multimodal cues. In addition, the elevated theta activity may reflect a more relaxed or meditative state, suggesting that AI-mediated interaction, free from real-time social pressure, allowed participants to regulate anxiety more effectively and engage with the task in a calmer mental state. The absence of face-to-face pressure and judgment in chatbot communication may have contributed to a more comfortable and stress-free environment, allowing learners to stay focused while feeling more at ease.

Research Question 3:

The final research question aimed to examine EFL students' perceptions of HHI and HCI in English-speaking tasks. Through thematic analysis, two main themes emerged for each interaction type. Perceived strengths and perceived challenges of human-human and human-chatbot interaction in English speaking context were identified for both groups. The HCI group mainly and frequently underscored a comforting and non-judgmental environment, the capability of ChatGPT to improve English-speaking skills, its persistent and 24/7 available conversational support as main strengths, while highlighting its inability to mimic human emotions, lack of non-verbal cues, and technical disruptions as major challenges. The human-human interaction group expressed that non-verbal cues, emotional connection, and active engagement in HHI held merit, causing more natural and effective communication. However, heightened

anxiety and fear of judgment were seen as major challenges in human-human interaction during English speaking tasks.

Previous research investigated EFL students' perceptions of the utilization of chatbots in the EFL context (Çakmak, 2022; Chen et al., 2022; Shikun et al., 2024; Thai & Chen, 2020; Yang et al., 2022). Yang et al. (2022) conducted a study to examine feedback from EFL students on the effectiveness of the chatbot "Ellie". 314 Korean students engaged in speaking tasks with Ellie and completed a survey to evaluate Ellie's performance and their experiences. The participants appreciated the convenience of the chatbot and expressed their gratitude for practicing English speaking in a non-judgmental environment, yet they identified its challenges in giving topic-related responses. Further, Shikun et al. (2024) analysed the students' perceptions of the employment of chatbots in language learning to identify potential advantages and disadvantages of chatbots in language classrooms. Many participants appreciated the stress-free and non-judgmental environment that the chatbots provide, while expressing their limitations in recognizing speech accurately. Besides, the students found the interaction with the chatbot less human-like. The results gathered from Chen et al. (2023) also support the idea that chatbots inherently lack emotional depth inherently exist in human interaction, according to the students' expressions.

Utilizing chatbots in English-speaking tasks has been widely acknowledged in the literature due to their fundamental benefits for learners, mostly featuring their effectiveness in alleviating anxiety (Du & Daniel, 2024). Previous research demonstrated that chatbot users experience a sense of comfort when interacting with them (Çakmak, 2022; Hsu et al., 2023; Jeon, 2022; Shikun et al., 2024). Hsu et al. (2023) proposed an interactive robot system to investigate whether it facilitates alleviating anxiety, and the results revealed its value in reducing speaking anxiety, which explains why the role of chatbots in anxiety mitigation plays a major role in the perspective of EFL students. Furthermore, Lee and Jeon (2024) conducted a study to examine the perspectives of young EFL learners on AI agents; their main findings provided consistent results to the current study. The learners expressed how they felt a sense of comfort when they interacted with AI agents. In a similar vein, Çakmak (2022) conducted a study on the examination of the human-chatbot interaction and its role in L2 speaking performance and anxiety, and the students appreciated the opportunity to speak L2 in a non-threatening environment. Even though most of the studies in the literature suggest that employment of chatbots in speaking tasks reduces

anxiety among learners, a case study conducted by Shazly (2021) found a contrasting result, reporting that AI chatbots slightly intensified learners' speaking anxiety. This divergence could be attributed to differences in the design and features of the chatbots used in the study. Valued for its crucial role in reducing the fear of speaking by offering a non-judgmental environment, chatbots were also appreciated for their persistent and round-the-clock availability as conversational assistants by the participants. Previous research also acknowledged its accessibility for the learners whenever, wherever they desire, which is not limited by human constraints (Haristiani, 2019; Kohnke, 2023; Winkler & Söllner, 2018). Although participants manifested several strengths, mainly in alleviating anxiety, they also identified challenges limiting their effectiveness as a conversational agent. The most frequent challenge identified by the participants was their inability to mimic human emotions. Investigating chatbots' employment in L2 learning from a perspective of self-determination theory, Annamalai et al. (2023) concluded that although chatbots facilitate a safe and engaging environment for the learners, the students are deprived of emotional attachment to the chatbots. Although prior research indicated that participants favoured and interacted more with chatbots exhibiting human emotions (Bilquise et al., 2022), users ultimately prefer human interaction because chatbots cannot fully replicate human emotions (Ockey & Chukharev-Hudilainen, 2020). Besides, non-verbal cues that were highlighted as one of the most vital features of human-human interaction by the participants in the current study were considered as critical factors in previous research as well (Gobron et al., 2013). In their study, Gobron et al. (2013) investigated the role of non-verbal cues in affecting the effectiveness of chatting in a 3D virtual environment by comparing a virtual agent and a human pretending to be an AI (Wizard of Oz). The results aligned with the current study revealed that non-verbal cues improved the enjoyment of the conversation and the emotional connectedness. Notably, the effect was stronger in human-to-human interactions. However, in their study, Maloney et al. (2020) revealed contrasting findings in terms of non-verbal cues in accelerating the effectiveness of communication. In the study, the primary aim was to explore the role of non-verbal communication in VR and its comparison with traditional offline and virtual interactions. The absence of non-verbal communication was viewed positively according to the reports of the participants since it reduced anxiety. By allowing the participants to communicate through text-based communication, it may be less intimidating for them.

To summarize, while the interaction with chatbots alleviated speaking anxiety among EFL learners by providing a stress-free environment, human-human interaction has been found to stand out in fostering emotional connectedness in EFL tasks, especially in speaking (Sherman et al., 2013). The current study's results of semi-structured interviews with the participants experiencing two different types of interaction appreciated the non-judgmental environment that chatbots offer while valuing the role of emotional connectedness, inherently salient in human-human interaction.

6. CONCLUSION

This study investigated the comparison between human-human interaction and human-computer interaction, especially AI-mediated chatbots during real-time English-speaking tasks from a neuroscientific perspective. With the employment of an EEG device placed on the scalp of the participants, this study mainly examined whether there were any differences in alpha and theta oscillations in two distinct interaction types during English speaking. Additionally, through obtaining expert opinions from neurologists and a comprehensive literature review, this study also sought to identify neural mechanisms underlying them, with a particular focus on memory mechanisms and relaxed states. Besides, this study also aimed to explore EFL learners' perspectives on human-human interaction and human-chatbot interaction during English speaking. Before the experiment, as the study is a clinical research and participants were selected from Yıldız Technical University, and ethical approval was obtained from both a clinical ethics committee and the Social Sciences Institute at Yıldız Technical University were obtained. After selection of participants based on predefined inclusion criteria, the participants were divided into two groups: one engaging in human-human interaction and the other in human-chatbot interaction, allowing for a comparative analysis of the two interaction types. Several questions were selected to encourage extended English-speaking durations, ensuring more effective and stable EEG data collection, as an optimal recording time of approximately 20–25 minutes was required. During the experiment, the EEG device, which measures brainwave activity by detecting electrical signals generated by neuronal activity via electrodes placed on the scalp, was employed in this study to investigate neural differences in two distinct interaction types. The study adhered to the Declaration of Helsinki, implementing the 10/20 electrode placement system. EEG data from each group's 24-minute real-time English-speaking session were recorded and analyzed using MATLAB with the EEGLab toolbox. To complement the EEG findings, qualitative data gathered from semi-structured interviews were analyzed using thematic analysis in MaxQDA, enhancing the validity of the quantitative EEG results.

Among the main investigations of the study, the results revealed significant differences in alpha oscillations in two distinct interaction types. The HHI group exhibited higher alpha activities in the frontal cortex compared to the ChatGPT group. By examining the differentiation in alpha oscillations in the frontal cortex, the study aimed to identify the neural mechanisms underlying them, as heightened alpha activity functions as an inhibitory mechanism that suppresses irrelevant information during memory retention. The observed differences in alpha power between HHI and HCI suggest that multimodal communicative environments, which incorporate verbal, visual, and gestural cues, facilitate memory retrieval and reduce cognitive effort. In contrast, the individuals engaged in chatbot interaction lacked multimodal cues, which may result in greater cognitive strain. The findings from theta oscillations also supported this result since higher frontal theta activity was observed in the HCI group, which revealed that the ChatGPT group had a greater reliance on predictive processing, resulting in more cognitive effort due to the absence of multimodal cues. Thematic analysis on semi-structured interviews also validated this finding since most participants identified the absence of non-verbal cues as one of the most challenging parts. Since the HCI group only relied on auditory input, they likely had to predict conversational flow, which resulted in higher theta activities, which allowed the individuals to maintain conversational flow when multimodal cues are absent, supported by the previous research. To illustrate, one of the participants noted that “You never experience the emotions immediately because you can't look someone in the eye, face to face. Instead, you find yourself waiting for a message from a chat, which makes it somewhat challenging”. In terms of memory retention, findings from both alpha and theta oscillations in the frontal cortex, along with qualitative reports indicated that cognitive load and retrieval efficiency differed in the two interaction types. The HCI group exhibited lower frontal alpha activity and higher frontal theta activity, which is closely associated with greater cognitive effort during memory maintenance, possibly due to the absence of multimodal cues, as the participants expressed.

In contrast, higher theta activity in the temporal cortex was observed in the ChatGPT group. Consistent with existing literature, the heightened theta activity in the temporal cortex has been associated with meditative states and relaxation. The participants engaged in English speaking tasks with a chatbot likely experienced greater comfort and less anxiety compared to those in human-human interactions. Along with the theta activity results, the qualitative reports also supported this finding as participants

frequently identified a sense of security as one of ChatGPT's strengths in facilitating English-speaking practice. As one participant described “Sometimes, I feel stuck when I speak English with a human, which often makes me worried about mistakes. However, I felt safe and comfortable practicing with ChatGPT.” These results indicate that AI-mediated interaction may help alleviate English-speaking anxiety, potentially creating a lower-stress environment for language learners.

Beyond its findings on memory mechanisms and a sense of relaxation in English individuals, this study also uncovered significant differences in temporal alpha activities in the ChatGPT group compared to the human-human interaction group. Heightened alpha power in the temporal cortex, consistent with the literature, is closely intertwined with auditory processing. Before the analysis, the differentiation in alpha oscillations in the temporal lobe was not planned as a variable to be measured in this study. However, upon analyzing the EEG recordings, significant differences were observed in the temporal lobes. Given the relevance of these findings, they were deemed notable and subsequently included in the study. This finding of this study indicates that the ChatGPT group had a greater reliance on auditory input, which, in turn, resulted in higher activity in the temporal lobes. This underscores the distinctive cognitive demands of AI-mediated English-speaking interaction, where auditory processing plays a more central role due to the lack of multimodal cues inherent in human-human interaction. Qualitative data further supported this observation, with participants emphasizing the importance of non-verbal cues in conversation. As one participant noted, “I believe you need someone to accept or at least refuse you with their gestures too. You need to be confirmed sometimes.”

6.1. Implications

The present study provided valuable insights into cognitive and neural mechanisms underlying human-human interaction and human-computer interaction, particularly chatbot-mediated communication, during real-time English-speaking. These results have significant implications for AI-assisted language learning, as it has been widely utilized in language learning in the last decade.

Firstly, the findings on distinct frontal alpha and theta oscillations in two interaction types offer a deeper understanding of memory mechanisms that are involved in English speaking performance. While those in the human-human interaction group appeared

to retrieve information more effortlessly, the ChatGPT group exhibited greater cognitive effort due to the heavy reliance on predictive processing. This finding highlights the multimodality effect in language communication, which plays a rather crucial role in conversation as it enhances both cognitive efficiency and emotional engagement. It also underscores the need for AI chatbots to incorporate multimodal features such as avatars, virtual gestures, and facial expressions to reduce cognitive strain and create a more natural interaction experience.

Furthermore, heightened temporal theta activity associated with mediative states in ChatGPT group along with the reports by the participants referred that the individuals experienced more comfortable English-speaking session through the engagement with ChatGPT. Given that foreign language speaking anxiety remains a significant challenge in language learning, chatbots can be utilized to mitigate the speaking anxiety by serving as a safe and pressure-free alternative environment for language learners.

This study also uncovered that higher temporal alpha activity was observed in the ChatGPT group, indicating more attentive listening activity. Due to the absence of non-verbal cues inherent in human interaction, the individuals solely relied on auditory input, which, in turn, resulted in increased attention to listening. This finding suggests that AI-mediated chatbots can be leveraged as a tool for improving listening comprehension in language learners.

While HHI in English speaking facilitates more engagement among learners through multimodal communication, AI-mediated chatbots offer practice opportunities for both educators and the learners. A blended approach combining these two interaction types, language learning outcomes can be optimized.

6.2. Limitations of the Study

Among the main limitations of the study, electrodes artefacts posed a challenge for the study as individuals can easily distracted in the recording session. Even though artefacts such as blinks or muscle movements were meticulously removed via MATLAB, the potential influence of residual noise on EEG data cannot be entirely ruled out.

Besides, the study's employing a one-shot recording session for each participant is another limitation in the current study. A repeated-measures design could provide deeper insights into the stability and consistency of neural responses over time.

Another limitation concerns the unequal distribution of participants between the two groups. While a total of 40 participants were invited, the HHI group comprised 20 participants, whereas the HCI group had 17, potentially affecting group comparability. Moreover, the study had a higher proportion of female participants than male participants, a demographic imbalance that is commonly observed in EFL classrooms.

6.3. Recommendations for Future Research

Given the challenges in EEG artefacts, future research should employ an EEG cap which rather minimizes the artefacts, thereby enhancing data quality. Besides, implementing multiple recording sessions should be considered to improve the consistency of EEG findings. A longitudinal approach could also provide insights into how neural activity adapts over time in AI-mediated and human-human language interactions. Additionally, future studies should arrange larger and more balanced participant groups to enhance the generalizability. Moreover, studies may explore broader participant profiles, including learners from different age groups, proficiency levels, and cultural backgrounds, to investigate how these factors modulate EEG responses during language interaction. In addition, further research can explore how multi-modal agents, such as virtual avatars with facial expressions and gestures, affect cognitive load, engagement, and memory retention in English-speaking tasks. Integrating a virtual agent into future studies could allow for a more nuanced comparison between human-human and human-computer interaction, shedding light on the role of multimodal communication in AI-assisted language learning. Lastly, incorporating other neuroimaging technologies such as functional Magnetic Resonance Imaging (fMRI) in tandem with EEG could open new pathways for neurocognitive analysis. While EEG excels at capturing rapid fluctuations in brain activity due to its high temporal resolution, fMRI offers superior spatial resolution, enabling the localization of specific brain regions involved in cognitive and emotional processing. Combining these modalities could provide a more comprehensive understanding of neural mechanisms underpinning human-human and human-computer interaction in language learning contexts.

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APPENDICES

Appendix 1. Clinical Ethics Approval

Evrak Tarih ve Sayısı: 13.06.2024-69534

ALTINBAŞ ÜNİVERSİTESİ
SAĞLIK BİLİMLERİ BİLİMSEL ARAŞTIRMA ETİK KURULU

Sayı: 8 **Tarih: 04.06.2024**
Konu: Arş. Gör. Gamze Turun

Sayın Arş. Gör. Gamze Turun
Yıldız Teknik Üniversitesi, Eğitim Fakültesi

İlgi: Yıldız Teknik Üniversitesi Eğitim Fakültesi Yabancı Diller Bölümü Başkanlığının 28.02.2024 tarihli yazısı ile Altınbaş Üniversitesi Sağlık Bilimleri Bilimsel Araştırma Etik Kurulunun 2024/11 sayılı yazısı.

Sorumlu araştırıcılığını üstlendiğiniz **2024/11** dosya numaralı **"Yabancı Dil Olarak İngilizce Öğreniminde İnsan ve Chatbot Etkileşimlerinin Karşılaştırmalı Analizi: Nörobilimsel Bir Perspektif."** başlıklı çalışma, kurulumuzun **30 Mayıs 2024 tarih ve 7 sayılı toplantısında** görüşülerek etik yönden uygun bulunmuş olup, tutanaklar ekte sunulmuştur.

Bilgilerinize sunarım.

Prof. Dr. Mustafa Aydın BARLAS
Sağlık Bilimleri Bilimsel Araştırma
Etik Kurul Başkanı
E-imzalıdır

Eki: Altınbaş Üniversitesi Sağlık Bilimleri Bilimsel Araştırma Etik Kurulu Karar Formu

ALTINBAŞ ÜNİVERSİTESİ SAĞLIK BİLİMLERİ BİLİMSEL ARAŞTIRMA ETİK KURULU KARAR FORMU

BAŞVURU BİLGİLERİ					
	ARAŞTIRMANIN AÇIK ADI	**"Yabancı Dil Olarak İngilizce Öğreniminde İnsan ve Chatbot Etkileşimlerinin Karşılaştırmalı Analizi: Nörobilimsel Bir Perspektif."**			
	ARAŞTIRMA PROTOKOL KODU	**2024/11**			
	KOORDİNATÖR/SORUMLU ARAŞTIRMACI UNVANI/ADI/SOYADI	**Ar. Gör. Gamze Turun**			
	KOORDİNATÖR/SORUMLU ARAŞTIRMACININ UZMANLIK ALANI	**İngiliz Dili Eğitimi**			
	KOORDİNATÖR/SORUMLU ARAŞTIRMACININ BULUNDUĞU MERKEZ	**Yıldız Teknik Üniversitesi Eğitim fakültesi**			
	ARAŞTIRMANIN TÜRÜ	Anket	□		
		Bilimsel araştırma	■		
		Diğer ise belirtiniz:			
	ARAŞTIRMAYA KATILAN MERKEZLER	TEK MERKEZ ■	ÇOK MERKEZLİ □	ULUSAL ■	ULUSLARARASI □

DEĞERLENDİRİLEN BELGELER			
1	İNDEKS	■	DİĞER: Tekniker ve stajerler için aydınlatılmış onam formu
2	AKADEMİK KURUL / KURUM KARARI	■	
3	OLGU RAPOR FORMU	□	
4	BAŞVURU FORMU	■	
5	HASTA TAKİP FORMU ÖRNEĞİ	□	
6	BİLGİLENDİRİLMİŞ GÖNÜLLÜ OLUR FORMU ÖRNEĞİ	■	
7	ARAŞTIRMA BÜTÇESİ	■	
8	DESTEKLEYEN KURULUŞ	□	
9	LİTERATÜR ÖRNEĞİ	■	
10	TAAHHÜTNAME	■	
11	İZİN BELGELERİ	■	
12	ÖZGEÇMİŞLER	■	

KARAR BİLGİLERİ		
Karar No: 8		**Tarih: 30.05.2024**
		Yukarıda bilgileri verilen araştırma başvuru dosyası ile ilgili belgeler araştırmanın gerekçe, amaç, yaklaşım ve yöntemleri dikkate alınarak incelenmiş, gerçekleştirilmesinde etik ve bilimsel sakınca bulunmadığına toplantıya katılan Sağlık Bilimleri Bilimsel Araştırma Etik Kurul üye tam sayısının salt çoğunluğu ile karar verilmiştir.

ALTINBAŞ ÜNİVERSİTESİ SAĞLIK BİLİMLERİ BİLİMSEL ARAŞTIRMA ETİK KURULU

Unvanı/Adı/Soyadı	Uzmanlık Alanı	Kurumu	Cinsiyet		Araştırma ile ilişki *		Katılım **		İmza
Prof. Dr. Mustafa Aydın BARLAS (ETİK KURUL BAŞKANI)	Farmakoloji	Altınbaş Üniversitesi	E ■	K □	E □	H ■	E ■	H □	e-imzalıdır
Prof. Dr. Hatun Hanzade DOĞAN	Tıp Etiği	Altınbaş Üniversitesi	E □	K ■	E □	H ■	E ■	H □	e-imzalıdır
Prof. Dr. Mehmet Soy	İç Hastalıkları	Altınbaş Üniversitesi	E ■	K □	E □	H ■	E ■	H □	e-imzalıdır
Doç. Dr. Şükriye Karadayı	Adli Bilimler	Altınbaş Üniversitesi	E □	K ■	E □	H ■	E ■	H □	e-imzalıdır
Dr. Öğr. Üyesi Gaye HAFEZ	Farmakoloji	Altınbaş Üniversitesi	E □	K ■	E □	H ■	E ■	H □	e-imzalıdır
Dr. Öğr. Üyesi Arzu Temizyürek	Fizyoloji	Altınbaş Üniversitesi	E □	K ■	E □	H ■	E ■	H □	e-imzalıdır

* :Araştırma ile İlişki
** :Toplantıda Bulunma

Appendix 2. Yıldız Technical University Ethics Approval

YILDIZ TEKNİK ÜNİVERSİTESİ
Sosyal ve Beşeri Bilimler Araştırmaları Etik Kurulu

Toplantı Tarihi: 16.07.2024 **Toplantı No: 2024.07**

SOSYAL VE BEŞERİ BİLİMLER ARAŞTIRMALARI ETİK KURULU TOPLANTI KARARI

Yürütücülüğünü Üniversitemiz EĞİTİM FAKÜLTESİ öğretim üyelerinden Dr. Öğr. Üyesi Semin Kazazoğlu danışmanlığında lisansüstü öğrencisi Gamze TURUN tarafından yapılacak olan "Yabancı Dil Olarak İngilizce Öğreniminde İnsan Ve Chatbot Etkileşimlerinin Karşılaştırmalı Analizi Nörobilimsel Bir Perspektif Comparative Analysis Of Human And Chatbot Interactions İn English As A Foreign Language Learning A Neuroscientific Perspective" adlı çalışma ve bu çalışmada kullanılacak veri toplama araçları ve yöntemlerine ilişkin bilgilerde etiğe aykın herhangi bir bulguya rastlanmamıştır.

Etik Kurul Üyeleri

[redacted]

Prof. Dr. Murat DONDURAN
Başkan

Taş Bina A-2013 Oda Davutpaşa Kampüsü Esenler/İstanbul Tel: (0212) 383 31 18
E-posta: sbemdr@yildiz.edu.tr - Web: sbe.yildiz.edu.tr
Rapor Doğrulama Adresi: "etik.yildiz.edu.tr/dogrula" Rapor No: 20240703188 Doğrulama Kodu: 1371f

Appendix 3. Informed Consent Form

Bilgilendirilmiş Gönüllü Olur Formu

Açıklama

Bu bilgilendirilmiş gönüllü olur formu İngiliz dilini yabancı dil olarak öğrenen kişilerin İngilizce dili öğrenim süreçlerindeki, chatbot kullanımının İngilizce konuşma aktiviteleri yapmadaki rolü ve İngilizce konuşma aktiviteleri yaparken chatbot ve insan etkileşiminin arasındaki nörolojik farklıkları analiz etmek için, Medical Park Bahçelievler Hastanesi'ne veri toplamak adına davet etmek için hazırlanmıştır. Çalışma Yıldız Teknik Üniversitesi Araştırma Görevlisi sorumlu araştırmacı Gamze TURUN, Yıldız Teknik Üniversitesi Doktor Öğretim Üyesi Semin KAZAZOĞLU ve Nöroloji uzmanı Dr. Öğretim Üyesi Emir Ruşen tarafından yürütülecektir.

Birinci Bölüm: Araştırma Hakkında Bilgi

Giriş

'' Yabancı Dil Olarak İngilizce Öğreniminde İnsan ve Chatbot Etkileşimlerinin Karşılaştırmalı Analizi: Nörobilimsel Bir Perspektif (Comparative Analysis of Human and Chatbot Interactions in English as a Foreign Language Learning: A Neuroscientific Perspective)'' adını verdiğimiz çalışmaya katılmak üzere davet edilmiş bulunmaktasınız. Bu çalışmaya katılımınız gönüllülük esasına dayanmaktadır. Araştırma kapsamında toplanan veriler, sadece bilimsel amaçlar doğrultusunda kullanılacak, araştırmanın amacı dışında ya da bir başka araştırmada kullanılmayacak ve gerekmesi halinde, sizin (yazılı) izniniz olmadan başkalarıyla paylaşılmayacaktır. İstemeniz halinde sizden toplanan verileri inceleme hakkınız bulunmaktadır. Sizden toplanan veriler korunacak ve araştırma bitiminde arşivlenecek veya imha edilecektir. Veri toplama sürecinde/süreçlerinde size rahatsızlık verebilecek herhangi bir soru/talep olmayacaktır. Yine de katılımınız sırasında herhangi bir sebepten rahatsızlık hissederseniz çalışmadan istediğiniz zamanda ayrılabileceksiniz. Bu çalışmada yer almayı kabul etmeden önce çalışmanın ne amaçla ve nasıl yapılacağını anlamanız ve katılıp katılmama doğrultusundaki kararınızı bu bilgilendirme sonrası özgürce vermeniz gerekmektedir. Araştırma hakkında sözlü olarak size aktaracağım bilgiler yazılı olarak da size bir sonraki bölümde sunulacaktır. Size özel hazırlanmış bu bilgilendirmeyi lütfen dikkatlice okuyunuz, sorularınıza açık yanıtlar isteyiniz. Bu belgedeki son bölüm onay işlemleri ile ilgilidir. Araştırmaya katılmayı kabul ederseniz lütfen bu bölümü imzalayınız.

Araştırma Hakkında Bilgi

Bu çalışmanın amacı, insan eğitmenler ile yapay zeka güdümlü bir sohbet robotu (Chatgpt) arasındaki Yabancı Dil Olarak İngilizce (EFL) öğrenme etkileşimlerinin nörofizyolojik etkilerini araştırmak ve karşılaştırmaktır. Çalışma özellikle, bu etkileşimler sırasında EEG cihazları tarafından kaydedilen EFL öğrencilerinin meditasyon, rahatlama ve dikkat seviyelerindeki farklılıkları ölçmeyi ve analiz etmeyi amaçlamaktadır. Araştırma, bu nörofizyolojik belirteçleri inceleyerek, etkileşimin doğasının (insana karşı yapay zeka) öğrencilerin bilişsel ve duygusal durumlarını nasıl etkileyebileceğini belirlemeyi amaçlamaktadır. Bu karşılaştırma, dil öğrenme

ortamlarında yapay zeka kullanımının etkinliği ve potansiyel faydaları hakkında içgörü sağlayacak ve teknoloji destekli dil eğitiminin daha geniş bir şekilde anlaşılmasına katkıda bulunacaktır. Bu araştırmada kullanılacak cihaz uzman nörolog doktor gözetimiyle gerçekleştirilecektir. Herhangi bir sağlık riski, potansiyel bir acı bulunmamaktadır. Bu çalışmaya İngiliz dilini yabancı dil olarak öğrenen, 18 yaşından büyük 40 yaşından küçük biri olduğunuz, herhangi bir nörolojik hastalığınız bulunmadığı için davet edilmiş bulunmaktasınız. Bu çalışma yaklaşık olarak 2,5 ay (10 hafta) sürecektir. Çalışmaya katılmadan önce size demografik bilgilerinizi belirleyeceğimiz bir form dağıtılacaktır. Ardından yaklaşık 8 hafta sürecek bu çalışmada belirlenen günlerde belirtilen hastaneye geleceksiniz ve sorumlu araştırmacı Araş. Gör. Gamze TURUN ve Nöroloji uzmanı Dr. Öğretim Üyesi Emir Ruşen gözetimiyle araştırma yürütülecektir. Deneysel grup chatbot aracılığıyla İngilizce konuşma pratikleri gerçekleştirecektir. Konuşma pratiği yapılırken EEG cihazı başınızda takılı olacak ve beyin dalgalarınız sonrasında incelenecektir. Kontrol grubu ise sorumlu araştırmacı Gamze Turun ile İngilizce konuşma pratiği yapacaktır. İnsan etkileşimiyle konuşma pratiği yapılırken yine EEG cihazı başınızda takılı olacak ve beyin dalgalarınız incelenecektir. EEG cihazından alınacak verileri Nöroloji uzmanı Dr. Öğretim Üyesi Emir Ruşen yorumlayacaktır. Çalışmanın en sonunda gönüllü katılımcılara 5 adet soru bulunan yarı yapılandırılmış görüşme yapılacaktır. Araştırma bir uzman tarafından gözetim altında yapılacağı için herhangi bir olası risk karşısında gerekli yardım yine uzman tarafından yapılacaktır. Daha önce de belirtildiği gibi, EEG cihazının beyne herhangi bir riski bulunmamakta ve araştırma sırasında herhangi bir acı hissedilmeyecektir. Araştırma sırasında istediğiniz zaman araştırmayı bırakacak özgürlüğe sahipsiniz.

Sorumlu araştırmacı Yıldız Teknik Üniversitesi Araştırma Görevlisi Gamze TURUN, Yardımcı araştırmacılar Yıldız Teknik Üniversitesi Dr. Öğretim Üyesi Semin KAZAZOĞLU ve Nöroloji uzmanı Dr. Öğretim Üyesi Emir Ruşen ile belirtilen hastanede chatbot kullanımının İngilizce konuşma pratiği yapma ile insan etkileşimiyle gerçekleşen konuşma pratiği yapma arasındaki nörolojik farkılılığın analizi konusunda bir araştırma yapılacağı belirtilerek bu araştırma ile ilgili yukarıdaki bilgiler bana aktarıldı. Bu bilgilendirmeden sonra böyle bir araştırmaya "gönüllü" olarak katılmak üzere davet edildim. Eğer bu araştırmaya katılırsam araştırmacılar ile aramda kalması gereken bana ait bilgilerin, gizlilik içinde, bu araştırma sırasında da büyük özen ve saygı ile korunacağı güvencesi verildi. Araştırma sonuçlarının eğitim ve bilimsel amaçlarla kullanımı sırasında da kişisel bilgilerimin özenle korunacağı konusunda bana yeterli güven verildi. Araştırmanın yürütülmesi sırasında herhangi bir sebep göstermeden araştırmadan çekilebilirim. Ayrıca tıbbi durumuma herhangi bir zarar verilmemesi koşuluyla araştırmacı tarafından araştırma dışı da tutulabilirim. Araştırma için yapılacak harcamalarla ilgili herhangi bir parasal sorumluluk altına girmiyorum. Tarafıma bir ücret ödenmeyecektir. İster doğrudan ister dolaylı olsun araştırma uygulamasından kaynaklanan nedenlerle olabilecek herhangi bir sağlık sorunumun ortaya çıkması halinde, her türlü tıbbi müdahalenin sağlanacağı konusunda gerekli güvence verildi. Bu tıbbi müdahalelerle ilgili olarak parasal bir yük altına da girmeyeceğim.

Bu araştırmaya katılmak zorunda değilim ve katılmayabilirim. Araştırmaya katılmam konusunda zorlayıcı bir davranışla karşılaşmış değilim. Eğer katılmayı reddedersem, bu durumun tıbbi bakımıma ve hekim ile olan ilişkime herhangi bir zarar getirmeyeceğini de biliyorum.

Bana yapılan tüm açıklamaları ayrıntılarıyla anlamış bulunmaktayım. Kendi başıma belli bir düşünme süresi sonunda adı geçen bu araştırma projesinde gönüllü olarak yer alma kararını aldım. Bu konuda yapılan daveti gönüllülük içerisinde kabul ediyorum. İmzalı bilgilendirilmiş gönüllü olur formunun bir örneğinin bana verileceğini de biliyorum.

Katılımcı Adı Soyadı:

Tarih:

İmza: